NAUTICAL
ROUTINE

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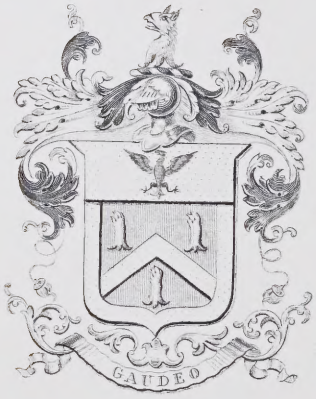


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# NAUTICAL ROUTINE AND STOWAGE, WITH SHORT RULES IN NAVIGATION.

BY

John McLeod Murphy, and W. N. Jeffers, Jr.

PASSED MIDSHIPMEN, U. S. N.

—:o:—

'Learn of the little NAUTILUS to sail,
Spread the thin oar, and catch the driving gale.'
* * * * *
'To instruct in what orbs the planets run,
Correct old Time, and regulate the sun.'

POPE.

PUBLISHED BY HENRY SPEAR,
CORNER OF WALL AND PEARL STS.
1849.

J. R. RICHARDSON Sc.

RPJCB

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JOHN M'LEOD MURPHY, ~~& W. N. JEFFERS, JUN.~~

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NEW YORK:
PUBLISHED BY HENRY SPEAR.
CORNER OF WALL AND PEARL STREETS.
1849.

Entered according to Act of Congress, in the year 1849,

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RPJC

TO

COMMANDER FRANKLIN BUCHANAN,

U. S. N.

THE ADVOCATE

AND

"STANDARD-BEARER"

OF THE

JUNIOR BRANCHES OF THE NAVAL SERVICE,

This Volume

IS RESPECTFULLY DEDICATED BY

THE AUTHORS.

# PREFACE.

THE aspiration of the man of patience, "Oh that mine enemy had written a book," was in itself harmless, compared with the wish, had it substituted the word *preface*—then, indeed, it would have been a sublimation of the patriarchal imprecation; and doubtless all who tread in the slippery and perilous pathway of authorship, can appreciate the pith of pious Job's revenge. Of late, however, in lieu of identifying these preliminary pages with the subject-matter of the volume, or volumes, (to which, in fact, they should serve as indices,) it has become the fashion to embody in them a repetition of Paul Pry's apology of "I hope I don't intrude;" and, if one may speak from inference rather than experience, oftentimes the labor and difficulty of disguising this, under the form and garb of a passable *excuse* for publication, amounts to more than all the other toils of authorship. The exception to this may be found—*et exceptio probat regulum*—in the preface of an author who tells us that his object is to benefit the human species, which aforesaid information virtually implies a claim to the rank, style, and cognomen of philanthropist. Another, whose daguerreotype is exhibited in the *Charcoal Sketches*, under the title of the "*Best-Natured Man in the World*," modestly shuns the responsibility of individual independence, and as if realizing his loss of it for the first time, blames in his preface the *friends*, whose cries of "Publish it!" "Publish it!" he could not possibly resist.

For my own part, and the world may call me what they please, I am free to admit that a great portion of the matter contained in this work was gathered at sea, and while (to quote the bard of Stratford-on-Avon, who is strongly suspected of having had an eye to windward) engaged in that *Much Ado About Nothing*, incident to a cruise in "these piping times of peace." Subsequently these notes were arranged in form, with the view of preparing myself for examination; at the close of which, the dread alternative presented itself either of giving up the toils of my midshipman days

to the cock-roaches, or that less book-loving fraternity, the *public;* and incited (like all other authors of course) by the hope, that as a printed manual of routine, they might be the means of imparting to the brows of my nautical brethren, a *wrinkle*, I hesitated no longer as to the course I should pursue. In view, then, of accomplishing this object, leave of absence was solicited from the Hon. Secretary of the Navy, and I set about the task of culling from a well-worn volume of half-obliterated notes, such as might be deemed worthy of publication. *Tupper* says, "Great is the dignity of authorship," and inasmuch as I confessed myself a convert to his "Philosophy," he might have spared me many a weary hour, had he added *great is the labor thereof*, for often the depth of my implication with the publisher proved a far greater incitement to "persevere unto the end," than all the promised "rewards" of a tenth edition. Later, when canvassing (so to speak) for what might be the fate of an offspring so *juvenile*, it was deemed advisable to increase the original limits of the work, so as to include STOWAGE and NAVIGATION; and in order to obtain a brief and concise treatise of the latter, adapted to the understandings of certain *anti*-mathematicians "too numerous to mention," the services of Mr. Jeffers were solicited, and though he embarked somewhat reluctantly into the perilous copartnership, the sequel will tell how far he has succeeded in the accomplishment of his task.

In reference to my own labors, I am by no means insensible of the possible existence of imperfections in the order of their arrangement; but all who have clambered from the "kelson to the truck," will bear me out in the assertion, that the science of seamanship is characterized by one distinguishing feature, peculiar to itself—viz. that its guiding principles, in lieu of being established laws of observance, are rather matters of *opinion;* and though based upon the infallible criterions of reason and practice, as unsettled in their adaptation to case and circumstance, as the elements upon which they are born and cherished. This peculiarity, coupled with the fact that no man's professional career "has been so eventful as to have made him experienced in every thing," must necessarily beset with incalculable difficulties the path of one who attempts to delineate its outlines: and perhaps the whole science may be truthfully defined to be, the application of *common sense* to the equipment and management of ships. Add to this, dear reader, the additional fact, that though writing under the shelter of "a leave of absence," the vicissitudes of the service are ever such, that I could have no guarantee for an unmolested probation on shore, and naturally enough I was kept in constant trepidation, as it were, by a sword of Damocles, in shape of orders to sea—a circumstance not only calculated to exterminate the

little ambition I felt to become an author, but to preclude, in some measure, that thorough treatment of the subject, which it was my design to give. But Pope says somewhere—

> "A hackney-coach may chance to spoil a thought,
> And then a nodding beam, or pig of lead,
> God knows, may hurt the very ablest head."

Nevertheless—to the point.

In the writing of the article on SPARS AND RIGGING, particular pains have been taken to render it as thorough as possible; and to refer to every improvement in marine equipments. For this reason, the best and most experienced riggers have been consulted, that their views might be obtained upon every point. Under these circumstances, I feel no hesitation in speaking boldly in its favor—for though emanating thus under my signature, it nevertheless embodies the opinions of men of the highest professional standing: knowledge of this fact, however, might have been gleaned from the absence of the *ipse dixit* throughout; for though presumptuous enough, as a Passed Midshipman, to write a book, I had neither the vanity nor the courage to associate the insignificant pronoun "*I*" with the detail of opinions and principles, of which many were in practical existence before "I" was born.

The EVOLUTIONS are a necessary accompaniment to the completeness of the work; although many of them are entirely new, at least to *print*. Among these I might enumerate "Backing and Filling in a Tideway"—"Reefing in Stays"—"Construction of a Temporary Rudder," &c., &c. These are from the *lips* (not the *pens*) of some of our most intelligent, practical, American merchant sailors, than whom *better* never braved

> "The lightning and the gale."

The subject of STOWAGE, which is drawn from the most authenticated sources, also embodies the rules and practice observed by the best *stevedores* of the present day. Hitherto the knowledge of this branch has been confined exclusively to that class of men; and despite the number and abilities of our nautical writers, this is believed to be the *first* methodized treatise ever presented in book-form. As it has added materially to the difficulty of my humble labors, this article is not offered without more than one silent wish, that it may be found equally useful.

To those who have kindly aided me in the accomplishment of this task, I confess my most grateful acknowledgments; and although it may be

invidious to mention any in particular, still I cannot lay down my pen without a momentary allusion to the memory of one, to whose abilities I owe many cherished obligations,—I mean Passed Midshipman Robert Savage, who, had he lived, would have won and worn the highest honors of professional distinction.

As an *ultimum vale*, I find it necessary to refer to some few comments, which I have made as notes, or otherwise, upon the works of other writers—more, however, with the view to remove any wrong impressions than to apologize for what I have considered my *duty*. With those gentlemen, I have not the honor of a personal acquaintance; neither have I regarded them as obstacles in my narrow and limited path of ambition, for I have no expectations or ends to serve in book-making, or authorship. What I have written has been done, *sans peur*, in full view and cognizance of the "golden rule."

JOHN McLEOD MURPHY, U. S. N.

THIRD-STREET, NEW YORK,
*March*, 1849.

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# SPARS AND RIGGING.

# PART I.

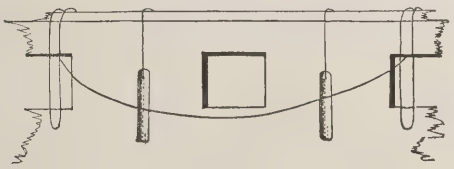
## SPARS AND RIGGING.

### SHEERS FOR LOWER-MASTS AND BOWSPRIT.

In the ordinary cases of masting, and particularly that of government vessels, the navy or dockyard sheers are resorted to, in lieu of temporary ones erected on board for the purpose. The manner of getting in, and stepping the masts by means of these standing sheers, is so simple, and so easily understood, that an explanation would in all probability be deemed superfluous. But as cases often occur, where it is necessary to erect sheers on board, the following method of rigging and raising them, is recommended, as that approved of by experienced and competent seamen.

Have a sufficiency of kentledge stowed to steady the ship for masting; shore the spar-deck fore and aft, best under the partner-beams, and sling fenders up and down the side, from the gunwale to the channels, and from the channels to the water-line; also, have skids from the gunwale to the deck, in-board, and chafing-mats on the quarter-galleries. Tow the sheer-legs alongside with their heads aft, and far enough to rest on the taffrail when on board. Lash a half-rounded spar on top of the gunwale, (well slushed on the upper surface,) for the parbuckles to lead over, when rove.

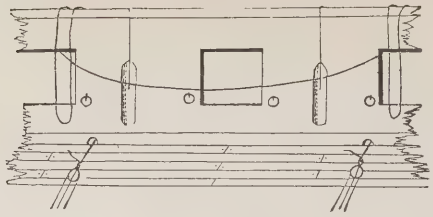
Fig. 1.



### THE MAIN, OR OUTER PARBUCKLES,

Are usually formed from a stout hawser, which is middled, and the ends rove from *out, in,* a few ports apart, with the bight *outside.* (See Fig. 1.) Pass the ends over the gunwale, down, and under the sheer-leg, (one at the head, and the other at the heel;) thence up again, over the bulwarks, and snatch them to blocks in the opposite waterway, (abreast of their respective ports,) and lead the ends to the capstan.

Fig. 2.



### THE COUNTER, OR INNER PARBUCKLES,

Are rove through the same ports, from *in, out,* having the bights over the gunwale *in-board,* (see Fig. 2,) and the ends taken down through the gun-deck ports, (or scuppers, if a sloop-of-war,) immediately under those of the spar-deck, through which they are rove, and a round turn taken over spars lashed *fore and aft* in the ports, (for the purpose of easing the sheer-legs down,) having hands to attend them. Have a stout spar laid across the gunwale aft, to rest the heads of the sheer-legs on, when on board. Man the capstan; heave round and raise the leg up to the gunwale; reeve the counter parbuckles over it; haul them taut, and disengage it from the outer ones, lowering the heel on deck, and resting the head on the athwartship spar, abaft. The other is taken on board in a similar manner.

Note.—Lieut. Fordyce, of the Royal Navy, in his "Outlines of Naval Routine," in reference to the subject of sheers, says: "When a vessel is confined to her own resources for spars to construct sheers, for getting in lower-masts, &c., the lower yards form the best—the yard-arms resting on deck should be fished, where they taper—woolded on, and the woolding set up by wedges. In a brig, the mainboom and mainyard are the best spars for sheers." It is almost needless to add, in corroboration of this idea, that the sheers for masting on board of merchant vessels are invariably constructed from the lower yards.

### SHEERS.

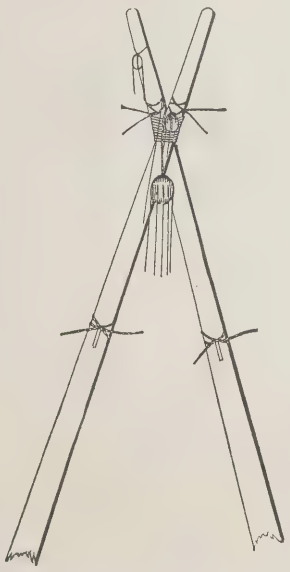
Cross their heads, and square their heels, spreading them about two-thirds the breadth of beam at the mizen partners. Pass the sheer-head lashing (which should be of well-stretched rope) either on the bight around the cross of the sheer-legs, and expend the ends alternately, and knot them; or pass a few turns of the figure-of-eight first, and after expending the ends, either hitch them to the forks, or knot them as above. The opinions in reference to this point are so various, that it seems almost impossible which to designate as the best method, while many seamen advocate figure-of-eight turns altogether.*

Immediately under the cross, lash a large threefold block, for upper one of main purchase, and spread the heels to the waterways, to tauten the sheer-head lashing. The strap of this block is sometimes fitted with a long and short leg, (see Fig. 4;) the former is passed over the sheer-head lashing with a round turn—through the eye in the short leg—hitched around the fork of the sheer-head, and then seized

* The Board of Examiners of the late graduating class at the Naval School, were also in favor of figure-of-eight turns for sheer-head lashings.

with spun-yarn. Another way is to fit it with two short eyes, which are secured under the cross by means of a lashing passed over that of the sheer-head. It should be remarked that these straps, however fitted, are *never* covered or served, in order that any indications of parting may be seen.

Fig. 3.



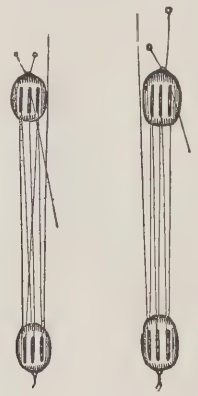
Next, lash a twofold block for upper one of small purchase to the after fork, having the cheek to rest against the sheer-head lashing, as a preventive from chafe. Higher up, on one of the forks, lash a girtline-block, (line rove,) for canting girtline: clove-hitch two good-sized hawsers around the cross, (see Fig. 3,) for forward and after head-guys; and about one-third the distance down each leg, another hawser for forward and after belly-guys, which should be cleated to prevent slipping. For SHOES, take two stout pieces of oak plank, of sufficient length to rest on three or four of the deck beams; cut mortices in them for the heels of the sheer-legs to rest in, and have stout eye-bolts driven in them to lash the heels, and hook shoe-tackles. Place the heels in the mortices, and lash them to the eye-bolts; hook forward and after shoe and heel tackles to straps around the heels of the sheers; take the lower block of the main purchase, and toggle it in the bowsprit-hole forward, or to the bitts, and reeve the fall by either of the following methods, which may be deemed preferable, viz:

1. The end which you intend for the standing part, is rove through the side sheeve of the upper block, from *forward, aft,* through side of lower, middle sheeve of upper and lower, and so on, terminating at the side sheeve of the lower block; from thence it is hitched to the fork above the cross-lashing.

2. Reeve the end through the middle sheeve of the upper block, middle one of lower, side of upper and lower again; thence *across* to side sheeve of upper; and lastly, through the remaining sheeve of the lower block, hitching it, as in the former case, to the fork of the sheers.

Each system has its advocates, as well as its objections. In the first case, we avoid chafe at the risk of slueing the block in the strap; and in the second, *vice versa*. It is, however, best, in seamanship, as in morals, "of two evils to choose the least;" and to adopt the first method, since the turning of the block is only a *probability*, while the chafing of the falls, by reeving with a cross, is an inevitable *certainty*.

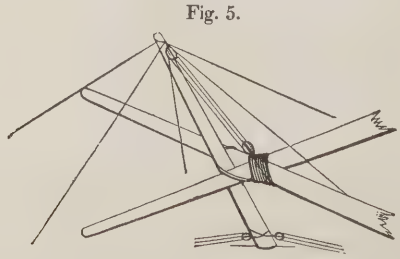
Fig. 4



Having rove the purchase, pass the fall around the capstan; lead the guys forward, having a luff-upon-luff on each, and man them well. Launch the sheers as far aft as possible without tripping them; take aft the forward shoe and heel tackles, and set them well taut. Pass a stout lashing around the heels and over toggles, (*outside* of the ports;) also to ring and eye bolts near at hand. Secure them firmly, and heave away, catching the sheers as they rise with the athwartship spar. When nearly erect, avast heaving; lash the heels in the shoes securely, take the forward shoe and heel tackles forward, and man them, tending the after ones; cast off the bulwark lashings, and transport the sheers just forward of the mizen partners, having previously dampened the deck to facilitate the operation, (moving but one leg at a time,) and rake them, so that the main purchase will hang plumb over the forward part of the mast-hole.

Many systems have been devised by seamen as auxiliaries in raising sheers, but the following simple and effectual method is among the best.

Fig. 5.



A small stout spar (say a stump top-gallant-mast) might be employed between the cross of the sheer-forks, where it could be retained by a loose lashing. Hook a stout tackle from the head of this spar to the sheers, and attach two other (canting and heel) jiggers together with head-guys, as in Fig. 5. With these, get it erect,

slushing the spar and the forks at their points of contact. Now, with the assistance of the tackle, the head of the sheers can be elevated to a considerable degree, and the main purchase made to act, at an angle sufficiently great, to raise the sheers without further difficulty.

## LOWER-MASTS.

The mizen is taken in first, to prevent the necessity of tautening the sheer-head lashing, which, on account of the decrease of beam, would become slack in transporting the sheers from forward, aft. Haul well taut the shoe and heel tackles; bring a strain on all the guys, and lash the heels to the bulwarks. Take the lower block of the main purchase through the sheer-legs *aft*, over the quarter, and toggle it to the garland on the mast, which should be towed alongside with the head aft.

As a diversity of opinion appears to prevail among seamen, as to the particular construction and positions of garlands, it is thought proper to add a few words in reference to this subject. Garlands, (represented in Fig. 6,) as employed on board of the French line-of-battle ship "*Hercule*," in taking out an injured mainmast, were formed of small stuff, (well stretched,) and passed around two posts, at a distance apart, and size, depending on the conditions of the case; the ends knotted, and the whole hitched over like a selvagee. The garland thus made, was placed on the *forward side* of the new mast *before launching*, at the distance of the *top of the gunwale*, to *the step in the kelson*, laid off *from* the *heel* towards the *head*. It was then secured to the mast by a cross-lashing as in the figure below, and the ends dogged, while a toggle was placed in the lower bight of the garland to prevent its rendering.

Fig. 6.

When both purchases are employed, as in the case above, in getting in heavy masts, a good plan, and one which obviates the necessity of heavers on the heel, is to lash the garlands a little on each side, and *not* in the same right line with the axis of the mast. Then, by slacking one purchase and holding on to the other, it may be slued at pleasure. The position of the small garland should be at the distance of *its purchase block, from that of the large one, on the sheers*, above the main, so that the falls cannot come two blocks except at the same time.

Man the capstan, (around which the purchases are passed,) and heave away until the mast-head is up to the gunwale; lash a pair of single blocks to the tenon—reeve the girtlines—bend the canting girtline to the mast below the bibbs, and sway again until high enough; ease the heel in-board with a jigger or guy, coming up the after quarter, and belly-guys, (on the side on which the mast comes in,) which must be set up again. Bowse upon the canting girtline, and point the mast fair for stepping; wipe the heel dry; have carpenters below in attendance; lower away; white-lead (some old sailors say tar) the tenon and mortice, and step the mast. Pass a couple of straps around the mast-head—sway up pendant tackles—hook and set them taut, wedging the masts temporarily. Come up the purchases, off garlands, and proceed to transport the sheer-legs forward for taking in the main-mast. Cast off the bulwark lashings; man the guys and heel-tackles, and move one leg at a time. Rake and secure the sheers as before. Take the main and fore masts in, in the same manner as the mizen, with the additional use of the small purchase. If the sheers should be rather short, the forks may be spanned together by a piece of rope, passed from one to the other, and the upper block of the small purchase lashed to the span. Another way is, to rest the heel of the mast on stout blocks of wood, reaching across two or three of the deck beams, and after securing the head by means of guys, to shift the garlands.

The tops and tressle-trees, can be swayed on board with a burton on the sheer-head, and placed over before transporting, or afterwards with the girtlines and burtons.

In the merchant service, it is usual now-a-days, to get in the lower-masts before launching; and indeed frequently to rig the ship *in toto*. This, of course, saves much time, and (where the facilities are afforded) perhaps after all, answers the purpose quite as well. The manner of masting, however, in both branches of the service is essentially the same, and the leading principles as here stated, will apply to all the cases of ordinary practice. Under these circumstances, a particular reference to the differences and coincidences which occur, would, in all probability, be regarded as an idle and wearisome repetition.

## BOWSPRIT.

Transport the sheer-legs forward, and rake the head over the bow, so that the lower block of the main purchase will hang just outside of the cutwater. Shift the upper block of the small purchase to the forward part of the sheers. Hook two stout tackles to the foremast head, and set them well up abaft; also two more from the foremast head to the sheers, or lash two large single blocks there instead, and reeve the after-guys through them, setting them up at the main bitts. Take the after-shoe and heel-tackles forward; tend the shoe-lashing, and lash afresh—setting all well taut. Secure the sheer-legs firmly to the bulwarks, and set the forward belly-guys up to the cathead. Previous to launching the bowsprit, put on the cap; also, the saddle for jib-boom, and lash the main-purchase garland on, so that it will hang *head* heavy, and the one for the small purchase just forward of the bees. Tow the bowsprit under the bow, and hook breasting-tackles from the eyebolts in the cap to each cathead, having a bedding-tackle in readiness also, to a strap around the heel.

The late Captain Glascock, in an excellent work, entitled the "*Naval Officers' Manual*," has added an *apropos* "caution" on taking in the bowsprit, which all

the other *writers* (not riggers) appear to have omitted, viz.: "The main purchase must be overhauled down abaft the bumpkin; for should the purchase fall be passed before, and *under* the bumpkin, it will be impossible to lift the bowsprit *higher*. The spar must necessarily be lowered again into the water, the purchase untoggled, and shifted abaft the bumpkin, and, in fact, all the work must be done over again."

Man the purchases, and sway up until high enough for canting; then haul on the small purchase, hook the bedding-tackle, (which leads from the bitts through the bowsprit-hole,) point the heel fair, wipe it dry, white-lead the step, bowse on the breasting and bedding tackles, ease away handsomely the purchases, and step the bowsprit. Come up the purchases and tackles, and cast off the garlands; take the after-shoe and heel-tackles abaft; tend the forward ones, and mast-head tackles, (or hawsers;) cast off the bulwark lashings, and, by means of the after heel-tackles, rouse the heels of the sheers as far aft as the forward tackles will allow; then lower the sheers on the rail forward; strip them; hook the fore and main pendant-tackles to straps around the heads and heels; sway up and breast them over the gunwale with channel-jiggers, sending down the extra pendants (or hawsers) from the foremast head, and setting up the tackles as before, to steady the masts.

---

## STANDING RIGGING.

Before a consideration of the subject of placing the rigging over the mast-heads, it is thought proper to refer in terms of brevity to the manner of cutting and fitting it, as being more directly in the natural order.

### MAST PENDANTS,

When fitted, should be the length of their respective cross-trees; in which case, the *after* one would be the longer: but why this difference in length should subsist of necessity, is a matter now perhaps lost among the "dim traditions" of seamanship. Although the custom appears to have had its origin in the calamities incident to the sea; and the forward legs, by being shorter, were probably designed as a substitute, in the event of the yard-slings being shot (or carried) away; while the after ones, on account of their superior length, could be employed (in connection with tackles) to support the mast, without interfering with the yard, in case of a similar accident to the lower stays.

In fitting the pendants, turn a large thimble (well parcelled) in the ends of each, thrusting the strands of the splice once and a half; and after scraping them down, serve about a foot above; observing, in all cases, where a thimble is turned in, in this manner, to pass the turns of the service *towards* the thimble. Thus fitted, the pendants are wormed, parcelled, and served in the wake of the mast-head; after which, they are spanned together with small stuff on each side, enclosing half the square of the mast-head, from the centre of each.

The size of rope required for lower pendants is thus laid down in the tables, viz.:

*Fore* and *main*, 74's, 10½ inch.; frigates, 10 to 9; sloops, 8 to 7½; brigs, schooners, &c., 6 inch.

*Mizen*, 74's, 8 inch.; frigates, 7 to 6½; sloops, 6 to 5½.

NOTE.—In the merchant service, lower pendants are now seldom if ever met with; all heavy purchasing being done by means of triatics, and discharging-tackles. As this rule is only applicable to government vessels, it should be observed in reference to the pendants of small craft, (or where a single one is used, as on the mizenmast,) to fit them with a cut splice, joining the two together on opposite sides of the mast-head.

## LOWER-RIGGING.

The best and easiest rule to obtain the length of the shrouds, in the absence of a draft, is to take the mean distance from the top of the *opposite* lower tressle-tree across the mast-head to the partners of the mast; *plus*, *two-thirds* of the distance to the lower dead-eye. This will give the length of the first pair of shrouds, which should be laid off on the floor of the loft, and the shrouding (from which the rigging is to be cut) *flaked* closely around two samson posts, fixed at the distance of the extremities of the first *pair*, apart. In this manner, we obtain all the other shrouds in the order of their succession over the mast-head. Now mark each pair in the bights (forming the eyes) with marline, having a number of knots in it, for designation; and after cutting through the opposite end of the flake in a right line with the samson posts, get the rigging on a stretch.

From the centre of the eye down the leg, lay off a distance equal to the length of the after lower cross-tree, (that being the length of the futtock-rigging,) *plus*, one foot; at which, place a mark on each leg, and after worming, (with the lay,) put on the parcelling, beginning at the marks on the shroud, and working *up* to the crown of the eye, in both cases, in order to make the rigging shed the weather; then clap on the service, which is passed *against* the lay of the parcelling. At the distance of four feet from the end of the shroud-leg, with about one-half the diameter of the dead-eye in addition thereto, mark off, and turn in the dead-eyes *temporarily*. Take the *fifth square* of the mast-head for the circumference of the eye of the first pair of shrouds, and pass the EYE-SEIZING, which is put on as follows: Heave both parts of the shroud closely together, by means of a strand, a little above the place where the seizing is to be put on, observing to clap on a layer of tarred parcelling, in order to protect the shrouding, and to make the turns lay fair and smooth. Splice an eye in one end, through which, and around both parts of the shroud, reeve the other, and pass the first turns (usually eight, being about the diameter of the rigging in width) *upwards towards* the crown; then thrust the end back, through the eye of the seizing, and the first and second turns, and pass the riding ones; after which, bring it down through the two last of the first turns, and frap all parts together, between the shroud-legs, forming a clove-hitch with the end in the frapping. All the other seizings are passed *from* the crown, once the diameter of the rigging *below* that passed on the previous pair, so that when the rigging is placed over, they may be situated in the same right line parallel to the tressle-tree.

The size of lower-rigging in merchant ships, depends as much on the proportion of spars as upon the class of vessels for which it is required; and although no universal rule can be laid down for the former, without the introduction of complex

and lengthy tables, an assimilation *might* be made between the rules for government vessels and those destined for the merchant service. The size for the different classes is stated as follows, in the books, viz. :—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Fore,* | 74's, | 10 inch. ; | frigates, | 9 inch. ; | sloops-of-war, | 8 to $7\frac{1}{2}$ ; | brigs, &c., | 6 inch. |
| *Main,* | " | $10\frac{1}{2}$ to 10 | " | 9 | " | 8 to $7\frac{1}{2}$. | " | 6. |
| *Mizen,* | " | 8 | " | 7 to $6\frac{1}{2}$ | " | 6 to $5\frac{1}{2}$. | | |

In the merchant service, it is usual to serve not only the forward swifters, but all the shrouds, the entire length. This custom, however, is not observed in the navy; a neat sword-mat being employed to protect the swifters.

N. B.—It should be remarked, that *all* the standing rigging used in the equipment of naval and mercantile vessels, is four-stranded right-hand rope; hawser-laid having gone out of date on account of its tendency to stretch.

## MAIN AND MIZEN STAYS

The rule as stated in the case of lower-rigging applies equally to the stays, with the additional length of the mast-head for the collars, the legs of which are laid up in the making, by leaving two of the strands long enough to double back and fit in the lay of the first half; while the bights thus formed by doubling, answer for the eyes. In fitting the collars, a backing of small yarns is used, and the *inside* ones from each strand are wormed into the stay some distance below the crotch; the legs are then wormed, parcelled, served, and leathered, down as far as (and to cover) the strand-worming on the stay.

The mizen, which is always single, is usually fitted with a shark's mouth for shackles on the mainmast, just above the deck; although frequently, in the merchant service, the lower end is *spliced* around the thimble of the shackle, and sets up by means of the eye-lashing aloft, Spanish-windlass fashion. In all other respects, the mizen is fitted like the main.

Again, the same difficulty is found in establishing a rule of size for merchant vessels, as in the case of LOWER-RIGGING; and in order to avoid lumbering up the narrow limits of the work with tables of reference, recourse must be had to the assimilation and comparison suggested in the preceding article, with due regard to the proportional disparity of masts. The rules for the naval service are thus laid down :—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Main,* | 74's, | 15 to $14\frac{1}{2}$ inch. ; | frigates, | 14 to $12\frac{1}{2}$; | sloops, | 10 to $9\frac{1}{2}$ ; | brigs, &c., $6\frac{1}{2}$. |
| *Mizen,* | " | $9\frac{1}{2}$ to 9 | " | 9 to 8 | " | $7\frac{1}{2}$ to $7\frac{1}{4}$. | |

## FORE-STAYS.

The rule as in the cutting, *size,* and fitting of main-stays, applies also to those on the foremast, with the exception of allowing *one-third* of the distance to where it sets up, in lieu of two, on account of the steeve of the bowsprit, and also the use of additional service, above the *nip,* to avoid chafe from the sheets and pendants forward.

Of late, a new system has been adopted in the mercantile marine, which, as yet

has not found its way into the naval service. There, the lower-stays are of one entire piece, passing under the bowsprit, and cleated, instead of reeving through the bees or setting up on the ends. They are fitted with lashing-eyes, and the crotch of the collar is formed by a seizing, binding the two stays together. This method, whatever be its peculiar advantages—perhaps only those of economy,—is accompanied by the insuperable objection of bringing the entire weight and upward strain of the foremast, in heavy pitches, upon the gammoning and bobstays; besides obliging one to shorten and refit the legs, (in consequence of coming "eye and eye,") every time the stay requires setting up, which, as will be readily perceived, must be done aloft.

### FORE-STAY STRAPS.

Although the method of reeving the stays through the bees has almost entirely superseded every other, the old custom of straps is sometimes adhered to; and as cases frequently occur where the bees split, or become otherwise injured, the following (but recently abandoned) is given, not only for the benefit of those whose prejudices for old systems still linger, but also in cases of accident to the stays when fitted after the "prevailing fashion."

Take a piece of new rope, (eight-inch for a frigate,) stretch it well, and cut it in length *four* times the circumference of the bowsprit where it is intended to be placed, and *twice* that of the stay; get it on a stretch again, worm and cover it loosely with canvas; splice the ends together, middle it, and seize lock-thimbles large enough to receive the stay in one of the bights, having the splice to lay in the score.

In point of looks, these straps are somewhat disadvantageous when compared with the late method; and it should be borne in mind that the fore-stays, when reeving through the bees, require more length, and an additional allowance of the distance from the bolt in the bow, to the sheeve in the bees, must be made.

### BOBSTAYS,

When of rope, are cut *twice* the length from their straps on the bowsprit, to the holes or shackles in the cutwater. They are wormed, parcelled, served, and leathered in the wake of the cutwater, and are fitted with a heart in the upper bight, which has the splice in the score, when rove. When chain is used instead of rope, they are only *once* the distance from the strap (or, in that case, *iron band*) to the shackle, *minus* one circumference of the bowsprit, which allows for a *rope laniard*, reeving through a heart, as in the method above. The heart is turned in with an eye-seizing, passed in the same manner as that referred to under the head of "Lower-Rigging." The size allowed for the vessels of the naval service is as follows:—

74's, 10½ inch.; frigates, 10 to 9; sloops, 8 to 7½; brigs, &c., 6.

### BOWSPRIT SHROUDS.

It is best to fit them of rope and chain, (half of each,) and in length, once the distance of their eye-bolts in the bow, from the strap on the bowsprit. The rope

part is fitted with a thimble in one end, which is connected to the chain by means of a shackle; the other extremity is spliced around a heart, and goes with a laniard, as in the case of bobstays. The splice of the thimble and heart should be served. In the merchant service, they are fitted entirely of chain, like the bobstays.

NOTE.—Care should be taken to exclude all service not absolutely essential to the preservation of the bowsprit rigging, on account of its retention of water, and the consequent tendency to produce rot.

### FUTTOCK-RIGGING.

In length, equal to the half of lower cross-tree, fitted with a hook and thimble in one end, and an eye in the other—wormed, parcelled, and served the whole length, care being taken to keep them on a stretch as long as possible before setting up. *They are always the size of the topmast rigging.* Rope has, however, fallen into general disuse, and in nine cases out of ten, futtock-rigging is iron, except in the instance of large vessels, as ships-of-the-line, &c.

### YARD-SLINGS

Are of chain, in length *twice* that of their respective mast-heads; to which must be added half the length of the forward lower cross-tree, that being the distance the yard should hang below the top.* The upper section, i. e. above the top, should be shackled together, keckled with a piece of large stuff to make it round, and neatly covered with canvas. The size of the chain necessarily depends on the weight it is required to support.

The yard-slings of merchant vessels are in length only half that of the forward lower cross-tree, and fitted with a hook which connects to an eye-bolt in an iron band going around the mast just below the eyes of the rigging. By means of this plan, the yards are found to brace much easier than when suspended *vertically*, as done in the navy; while at the same time the slings acting at an angle serve to relieve in some measure the strain which is brought upon the truss by the sail bellying forward. Objections are, however, raised by many seamen, (notwithstanding the economy of the method,) on account of the necessity for slinging the yard *perpendicularly*, by a temporary lashing from the mast-head, in the event of having to house, or shift the topmast; since it is evident that the mast could not be stirred without resorting to this expedient, or to the more laborious one of sending down the yard to the deck beforehand.

### TOPMAST SHROUDS

Should be cut the neat length from topmast-*head* to fid, and fitted in all respects like the lower-rigging, with the exception that the forward swifters are served all the way, (to avoid chafe from the topsail-yard,) and sister blocks for the lifts are

* It will be observed that the suggestion offered under the head of MAST-PENDANTS, in reference to their length, has a direct relation to this point.

seized between the first and second shrouds, just clear of the bolsters; and *not* between the swifter and first shroud, as recommended in some of the books; as the pressure of the yard, in clewing down, on the lee side is apt to split the shell; care being taken to seize the one on the *port* side the diameter of the rigging further *below*, so that it may be in the same right line with the one on the starboard side.

The size of rope for topmast rigging, varies much with the particular opinion the rigger may entertain with regard to its utility; for many seamen hold, that it is of little or no absolute service, except as a means of ascending and descending from aloft. But the contrary of this estimate is satisfactorily exemplified in the fact, that where vessels have been obliged to lose their topmasts, it is *always* necessary to cut away the laniards of the shrouds, after the backstays have been severed, in order to get rid of the mast. A reference to the following extract from the Tables of the naval service, compared with the size of lower-rigging previously stated, gives as a general rule an average of six-tenths.

*Fore and main,* 74's, 7 inch.; frigates 6 to $5\frac{1}{2}$; sloops, $4\frac{1}{2}$ to $4\frac{1}{4}$; brigs, &c., 4 to $3\frac{3}{4}$.
*Mizen,* " $5\frac{1}{4}$ " 5 to $4\frac{1}{2}$ " $4\frac{1}{4}$ to 4.

## TOPMAST AND SPRING STAYS.

For length, take the distance from the after-part of their respective mast-heads, to where *they lead* and set up. They are fitted in all respects like the lower-stays, being leathered in the wake of the bees, clump-blocks, or whatever they reeve through. It should be remarked, however, that this rule has regard to the diversity of manner in leading stays; some being brought to the deck, (as in the case of those of the main-topmast,) while others are made to perform the service of bowsprit, shrouds, &c. And again, in the merchant vessels of the present day, they are sometimes fitted to go around the bowsprit, and cleated, like the lower-stays, already mentioned. The best manner of leading them, is to reeve the fore through the bees, and set them up to the bow—to bring *one* of the main to the deck, without regard to the foremast-head, and the mizen to the main-top.* The size we find laid down as follows, for the different classes of vessels:

*Fore and main,* 74's, $9\frac{1}{2}$ inch.; frigates, 9 to $8\frac{1}{2}$; sloops, $7\frac{1}{2}$ to 7; brigs, &c., $6\frac{1}{4}$ to $5\frac{1}{2}$.
*Mizen,* " 6 " $5\frac{1}{2}$ to 5 " $4\frac{3}{4}$ to $4\frac{1}{2}$.

## STANDING AND BREAST BACKSTAYS

Should be cut the neat length from the mast-head to their respective channels. The *standing* ones go over the mast-head like the shrouds, and are fitted in the same manner, being covered with raw-hide, or served in the wake of the tops and lower-yards, (when braced up.) The *breast-backstays* are single, and fitted with a small neat eye, which is parcelled and marled over.† A good-sized double-block is turned in the lower end for the fall to reeve through; the bight forming the strap of the

* The mizen-topmast has no spring-stay, of course.
† The best plan; as it admits of their being sent down in port.

block, should be made long enough to turn it out in case of necessity without drawing the splice, having a seizing close down to the block.

The breast-backstays should be covered, or served in the same manner as the standing ones.

The Tables give us the following estimate sizes, viz :

*Standing.* { *Fore and main,* 74's, 10 inch. ; frigates, $9\frac{1}{2}$ to 9 ; sloops, 8 to $7\frac{1}{2}$ ; brigs, &c., $6\frac{1}{2}$ to $4\frac{1}{2}$.
*Mizen,* 74's, $7\frac{1}{2}$ inch. ; frig. $7\frac{1}{4}$ to 7 ; sloops, $6\frac{3}{4}$ to $6\frac{1}{2}$.

*Breast.* *Fore and main,* " 8 to $7\frac{1}{2}$ ; " 7 ; sloops, 7 to $6\frac{1}{2}$ ; brigs, &c., $5\frac{1}{2}$.

Merchant vessels are now seldom fitted with breast-backstays ; the standing ones being made to perform the service of both. This plan, in addition to its economy, is not without reason ; for it is manifest, that when sailing by the wind, the masts are strained forward in the direction of the lee bow, and consequently require support from *abaft.* The size of the backstays is usually that of the lower rigging.

## JIB-STAY.

Take the distance from the topmast-head, to where it leads and sets up, for the length. It is fitted either with a neat flemish eye in the upper end, and lashed to the collar of the topmast-stay, or with legs, to go abaft the mast-head, as in the case of the other stays. The latter method is preferable, however, for by lashing it to the topmast-stay, the entire weight and strain of *two* stays, one of which supporting a heavy sail, is brought upon *one* collar. In either case it is wormed and served, or leathered, a few feet below the crotch or lashing, to avoid chafe from the foot of the top-gallant-sail. The other end is pointed, and a small becket worked in, to bend a marrying-line. The size of the jib-stay for the different classes of vessels in the naval service, appears thus :

74's, 8 inch ; frigates, $7\frac{1}{2}$ to 7 ; sloops, 6 to $5\frac{1}{4}$ ; brigs, &c., 5.

## TOP-GALLANT RIGGING.

The *shrouds* should be the neat length of their respective topmasts and top-gallant-masts, when set up in the top, (in which case futtocks are dispensed with ;) otherwise, the length of the top-gallant-mast only; wormed, parcelled, and served in the wake of the cylinder, and below the futtock staff, except the forward one, which should be served the whole length. They are made to extend entirely across, and to fit so snugly as to require being driven on. The eyes are formed by means of seizings on each side—a bull's-eye being seized in between the first and second shrouds, just below, for the top-gallant lift. In the case of odd shrouds, (which are seldom met with in the merchant service,) they should be fitted with horse-shoe eyes or cut splices, or in one with the standing backstays.

The size is stated as follows, viz. :—

*Fore and main,* 74's, 5 inch.; frigates, $4\frac{1}{2}$ to 4; sloops, $3\frac{1}{2}$ to 3; brigs, &c., $2\frac{3}{4}$.
*Mizen,* " $3\frac{1}{2}$ to $3\frac{1}{4}$ " 3 " $2\frac{3}{4}$.

The *standing backstays* are cut the neat length from the mast-head to the channels, and fitted with horse-shoe eyes, which are wormed, parcelled, and neatly covered with canvas. They should also be leathered, or served in the wake of the tops and lower-yards, when braced up; and, in size, are somewhat larger than the shrouds, as will appear by the following extract from the Rigging Tables:—

*Fore and main,* 74's, 6 inch.; frigates, $5\frac{1}{2}$ to 5; sloops, $4\frac{1}{2}$ to 4; brigs, &c., $3\frac{1}{2}$ to $2\frac{1}{4}$.
*Mizen,* " $4\frac{1}{2}$ " 4 to $3\frac{3}{4}$; " $3\frac{1}{2}$ to $3\frac{1}{4}$.

The *breast-backstays* are the same length as the standing ones, and fitted with a small eye in the upper end, which is marled over; the other has a single block turned in it, for the fall to reeve through. They are leathered or served in the wake of the tops; and in size they should correspond with the top-gallant shrouds.

The *fore* and *aft stays* (in length) should be cut the mean distance from the mast-head, to where they lead and set up, of the same sized rope as their respective breast-backstays, except the flying-jib-stay, which is somewhat stouter. They are fitted with a neat round eye, (in English vessels, sometimes a running eye,) to go snugly over the cylinder, which is wormed and covered with canvas,—needing no protection, on account of being put over *first,* except a few inches of parcelling and service, just below the splice of the eye.

The rule for the length, as stated above, is applicable to the various methods of leading the stays, as the stretching (if cut from the coil) allows for the eyes and ends. The *fore* reeves through the *outer* sheeve in the jib-boom end; the *main,* through a sheeve in the after chock of the fore-topmast cross-trees; and the *mizen,* through a hole or roller in the after part of the main lower-cap. The *flying-jib*-stay is cut and fitted in the same manner as the fore-top-gallant stay, with the addition of parcelling and service in the eye, (on account of going over *last,*) and leather for a few feet below, to avoid chafe from the foot of the royal. The lower end should be pointed, and a neat becket worked in to bend a marrying-line.

The size of the flying-jib stay is a trifle larger than the top-gallant shrouds, viz.:

For 74's, 5 inch.; frigates, $4\frac{1}{2}$ to $4\frac{1}{4}$; sloops, 4 to $3\frac{1}{2}$; brigs, &c., $3\frac{1}{2}$ to $3\frac{1}{4}$.

## ROYAL RIGGING.

The *shrouds,* which are single, should be led into the top in lieu of setting up to the cross-trees, as they bring a heavy upward strain on the horns in lee-lurches, which might better be obviated, and more support given to the mast, by (lowering their point of security,) and having them to extend further below. In that case, cut them the neat length from the hounds of the royal-mast to the topmast fid; leather them in the wake of the jacks, cross-trees, and futtock-staves, and turn small single blocks in the ends for gun-tackle purchases, which will save the necessity of breast-backstays.

The *backstays* are the neat length from the hounds of the royal-mast to the deck, and are fitted in one with the shroud; the eye (which is wormed, parcelled, and covered with canvas) is formed by seizing the shroud and backstay together on each side, and made to set snugly over the hounds, a small bull's-eye or thimble being seized between the two for the royal lift. The *fore-and-aft stays* should be in length the neat distance to where they lead and set up, fitted in all respects like the top-gallant stays, being leathered in the wake of sheeves, rollers, &c. The size of royal rigging is thus laid down in the Tables:—

| | | |
|---|---|---|
| *Shrouds and Backstays.* | *Fore and main,* | For 74's, 4 inch.; frigates, $3\frac{1}{2}$ to $3\frac{1}{4}$; sloops, 3 to $2\frac{1}{2}$; brigs, &c., $2\frac{1}{2}$. |
| *Do. do.* | *mizen,* | For 74's, 3 to $2\frac{3}{4}$; frigates, $2\frac{1}{2}$ to $2\frac{1}{4}$; sloops, $2\frac{1}{4}$ to $1\frac{3}{4}$. |
| *Fore-and-aft Stays.* | *Fore and main,* | For 74's, $3\frac{1}{4}$ inch.; frigates, 3 to $2\frac{3}{4}$; sloops, $2\frac{3}{4}$ to $2\frac{1}{2}$; brigs, &c., $2\frac{1}{4}$ to 2. |
| *Do. do.* | *Mizen,* | For 74's, $2\frac{3}{4}$; frigates, $2\frac{1}{2}$ to $2\frac{1}{4}$; sloops, 2 to $1\frac{3}{4}$. |

NOTE.—It will be borne in mind, that the foregoing measurements, in all cases, suppose the masts to be fidded.

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In a review of the *approximate* rules just given, (for they claim to be little else,) it will appear that many of them are so general, and so widely framed, as to lack that dependence in accuracy which strict economy demands. But it must be remembered, that the prejudices and opinions of seamen in reference to rigging are so various and conflicting, that the system of each would require some particular and special rule of guidance. Under these circumstances, no *invariable one*, which will stand the infallible test of universal application, beyond a mere "rule of thumb," can be substituted for the absolute and proper measurement of drafts. Recourse ought, therefore, *always* to be had to the most accurate means; and no ship is complete in her outfit, which is permitted to sail without a draft of her spars and rigging.

The process of executing a draft, sufficiently accurate for practical purposes, consists simply in a reduction (by means of a scale) of the dimensions of the vessel's spars to a *side view*, showing the height and length; and also one of a *cross-section*, showing the circumference of mast-heads, &c., in order to illustrate the absolute spread and angular action of the shrouds and backstays.

The foregoing article may appear, in many respects, incomplete without a particular reference to other of the standing rigging than that comprised within its limits; but it has been found, that the exclusion of such as appertains to the yards, &c., here, will tend to obviate many of the wearisome repetitions, which, under a different arrangement, would be unavoidable hereafter. Sufficient, it is hoped, (however briefly and imperfectly expressed,) has been said, to illustrate such of the principles of equipment practised at present, both in the navy and mercantile marine, as was designed under this head, and to call the attention of the reader to such of the defects and sacrifices (suggested by false ideas of economy) as have been deemed necessary for his consideration. The objections offered here, it will be perceived, refer almost exclusively to the merchant service, and to that recklessness of appearances and security which is manifested to so great an extent, in carrying

out some ruling passion of narrow-minded avarice, or false principle of frugality,—in all of which, their apology seems to consist, in lightness of spars and sails, and that disregard for symmetrical proportions, characteristic of vessels of war.

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## BOWSPRIT.

Within a few years a complete change has taken place in the rigging of vessels destined for the merchant service; and to such an extent has the introduction of iron been carried, that the system may be said to have been entirely revolutionized. The substitution of iron for rope in the fitting of yards and bowsprits particularly, has become so universal, that the rules of the two services are now quite distinct. The comparative use of iron in the navy, on the contrary, has been so slow and unfrequent, as to be even painful to observe; and in this respect, it is perhaps *far* behind the improved condition arrived at, in the economical equipment of merchant vessels. It is urged, however, that the "splinters," resulting from the use of iron, (in the event of action,) are so formidable, as to render an introduction of it, as universal as that observed in the merchant service, highly objectionable; and also, that the "give," or yielding properties, are so slight, when compared with the elasticity of rope, as to endanger the spars by the sudden check of heavy and violent lurches; while increased weight, and the influence of temperature, are arrayed in the same ranks of opposition. But the advocates of the "old gray" system seem to have lost sight of the idea of *rope laniards,* in connection with chain bobstays and bowsprit shrouds, and to be mindless of the many unanswerable refutations of practice and experiment in our commercial marine. Without digressing, however, from our subject, further than to point out such defects and omissions as are deemed most important, it is proposed to state the system of rigging in the navy, and to make reference under the proper heads, to the difference of equipment in merchant-vessels, wherever such difference may be found to exist.

As the bowsprit is invariably rigged first, either for the purpose of getting it down in its place before gammoning, or otherwise, it becomes necessary to prepare a stage under it for the men to stand on, which is rigged as follows: Secure the heads of two small spars (as top-gallant studding-sail booms, for example,) together in a lashing hung from the bowsprit end, and rest the heels on the head-rail, where they should be seized, to prevent their slipping, and lay boards across from one boom to the other. If the fore-stays should *not* reeve through the bees, as recommended in the preceding article, but be fitted with straps, then measure two-thirds the length of the bowsprit *from* the knight-heads, *out-board,* for the point to put the strap for the port stay, fitted in the manner described on page 10, as done on board of the frigate "Cumberland," while flag-ship of the Mediterranean squadron.

Place the strap on the bowsprit, with the bight *uppermost,* in order that it shall not turn, while setting up the stay, (which would be the case were the reverse of the rule observed,) and put the thimbles through the other two bights, bringing them up again, so that those for the fore-stay shall be on the port, and those for the spring-stay on the starboard side; being careful that the parts do not ride on the bowsprit, and to place a seizing close down to the bights. Next to this, put on the

strap and *heart* for inner-bobstay; then strap and *heart* for each bowsprit shroud. Once the diameter of the bowsprit further out, place the strap and thimbles for the spring-stay, (fitted as in the other case;) then strap and *heart* for outer-bobstay. Next, strap and thimbles, usually called "spectacles," for topmast and spring-stays to lead through—if used as outer bowsprit shrouds, and not rove in the bee-sheeves; otherwise a strap and heart for each of the latter. Lastly, just outside the bees, place the strap and heart for cap-bobstay.

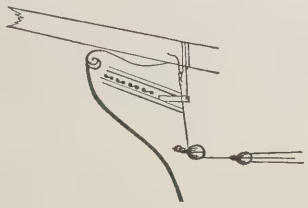
Reeve, middle, and splice the bobstays, and seize in the hearts for a full due at the splice, (in the same manner as the eye-seizing passed on the shrouds of the lower-rigging,) having a strip of tarred canvas in the score, and stitching leather around in the wake of the cutwater. Splice the end of each bowsprit shroud around a heart, and reeve a few turns of the laniard (on the bight) to give the rigging a fit, and set up the bobstays and bowsprit shrouds *temporarily*. Strap the fore and foretop-bowline blocks, (the former to the fore-stay straps, the latter to eye-bolts in the bees,) and proceed to gammon the bowsprit.

Note.—In lieu of *straps* for bobstays and bowsprit shrouds, *iron bands* are in universal use on board of merchant vessels.

## GAMMONING

Although iron for gammoning has almost universally superseded rope, it is, nevertheless, liable to accident; and as a prejudice still exists in favor of the latter, among the "old time" sailors, the following method of passing it, is that most approved of by experienced riggers:—

Fig. 7.

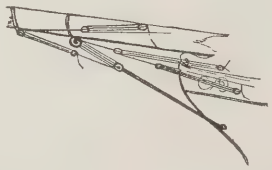


Tar and leather the bowsprit in the wake of the gammoning, having the latter laid on the upper surface, sufficiently wide to come back and cover all the turns when passed; and place the bolsters (usually of soft wood, well protected with layers of parcelling) in the *upper* part of the scuttle. Take a piece of well-stretched* *right-hand* rope, (which is preferable to hawser-laid, on account of the constant tendency of the latter to stretch,) and splice an eye in one end, and whip the other. Pass a turn of the gammoning around the bowsprit, *up* through the eye, over, and down, cleating it abaft to prevent its slipping, and set it well taut with a luff and pendant, which is fitted with a hook and thimble at each extremity, and rove through a single block secured to the bobstay-holes in the cutwater, by means of a strap sufficiently long, to allow the pendant to lead in a direct line through the hawse-hole, where a luff-tackle is clapped on, as illustrated in Fig. 7. Reeve a turn of the gammoning *against* the sun round the bowsprit and down

* "Or half-worn rope."—*Glascock.*

through the scuttle; form a bight with the end; thrust in a toggle, and put a strap around both parts above the latter, to which hook the outer end of the pendant, setting it well taut, and racking each turn respectively. Pass the balance of them, (usually seven,) in the same manner, from *aft, forward,* until the scuttle is filled; then take the end *back,* between the bowsprit and gammoning, and frap all parts together with it, using jiggers from each fore-tack bumpkin. Secure the end by a seizing; cut the rackings, (in order that each turn may share equally in the strain;) haul over the leather, (from *forward, aft,* that the inclination of the bowsprit may cause it to shed the spray,) and tack it down. If double gammoning is required, (as on board heavy ships,) pass the *inner* in the same manner—since, if the *outer* turns were passed last, the inner ones would become slack—and set up the bobstays and bowsprit shrouds for a *full due,* using a luff-upon-luff on *each* end of the laniard, as illustrated in the annexed figure.

Fig. 8.



Note.—Of late, quite a number of merchant vessels have been fitted *without* gammoning, by giving additional strength to the step of the bowsprit. This, so far as *security* is concerned, has been found to answer all the conditions, and tends somewhat to vitiate the impressions formed with regard to the intensity of strain caused by the foremast. But in almost every case, there is a sacrifice of *length* in the bowsprit, (compared with the old *régime,*) which must contribute to affect materially the sailing capacities of a ship, by precluding that exposure of sail-surface forward, essential to rapidity of movement and ready obedience to the helm; besides imparting to a vessel a short and chubby appearance, far from pleasing to the eye of a seaman.

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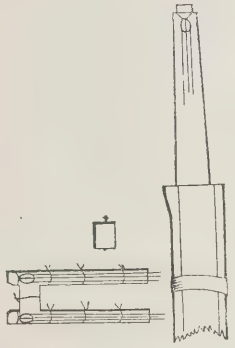
## RIGGING LOWER-MASTS.

In getting up the lower tressle-trees—if not placed with the sheers, which is done by means of spans—remove the pendant-tackles mentioned on page 6, and send a couple of stout burtons to the mast-head, secured at each side, with the cheeks resting against the tenon.

Place the tressle-trees on deck, *forward* of the mast, and take out the *after*-chock, as the forward one, by having to support the heel of the topmast is more securely bolted, and consequently not designed to be removed. Hook the lower block of each burton to a strap around the *forward* horns, and stop the standing-parts along to the after ones; white-lead the mast-head and tressle-trees in the wake of each other; bend on a guy from forward, sway aloft, and as the horns rise above the bibbs, cut the stops, (a hand having been previously sent aloft,) and work them into

their places. Send up the after-chock and bolt it. Now place and *lash* (not nail) the bolsters, having them made of soft wood, and covered with three or four thicknesses of tarred parcelling. Tar the mast-head in the wake of the rigging, and get over the lower pendants, which are swayed up by the burtons, hooking in the pendant-tackles, and setting them taut to steady the mast until rigged.

Fig. 9.



This plan is preferable to that of spans, on account of its security, and the perfect command which the burtons, by being stopped down to the tressle-trees, afford. In the merchant service they are invariably sent up by the sheers, almost simultaneously with the stepping of the mast.

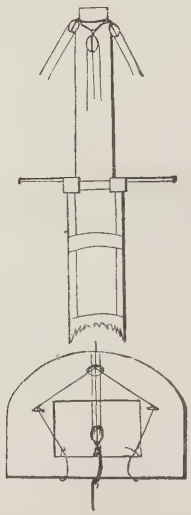
## WHOLE-TOPS.

Although half-tops have almost universally superseded the use of whole ones, except now and then in the merchant service, and the smaller classes of war vessels, the following plan of getting them over, is that adopted by an old and experienced rigger.

Have two stout girtlines secured at the tenon of the mast-head, and a good-sized single, or double tackle, hooked to a strap in the central part and directly between the girtlines, as in Fig. 10. Place the top on deck *abaft* the mast, with the forward part uppermost. Overhaul down the girtlines and tackle ; pass the ends of the former underneath the rim and make them fast to their own parts, around the after-part of the top, stopping them out to each girtline-hole, as in the figure. Hook the lower block of the mast-head burton to a stout strap around the after-part, (to which a guy is also attached, *leading aft*,) and secure the *standing-parts* of the tackle and girtlines to the pigeon-hole by means of a squilgee-toggle, over which the bights are laid. Bend on a tripping-line to the toggle, (which should be greased,) man the burton and girtlines and sway away, pulling up steadily on all. When the forward rim comes up to the block, jerk on the tripping-line, (which disconnects the parts, and permits the girtlines to go out to the side, and lead off fair ;) sway on the tackle until the lubbers'-hole is clear of the mast-head, and lower away by means of the girtlines, sending it aft or forward with the tackle and guy as need be, having previously white-leaded the tressle-trees in the wake of the cross-trees, which are either secured to the top before sending it aloft, or sent up by means of the girtlines, first.

Bolt and secure the top with keys to the tressle-trees, ship the futtock and top-plates, stanchions, rail, etc., and send down the tackle and girtlines. It has been proposed to send two men up with the top, who hold the slip-ropes in their hands, and whose office is to cut the stop at the pigeon-hole; but this method was objected to by the late Board of Examiners at the Naval School, on the score of danger, and perhaps not without good and sufficient reason. The plan usually resorted to, is to send a man aloft beforehand, who cuts the stop; but even this, is liable to the same objection, and the first method, after all said and done, is the best and safest.

Fig. 10.*



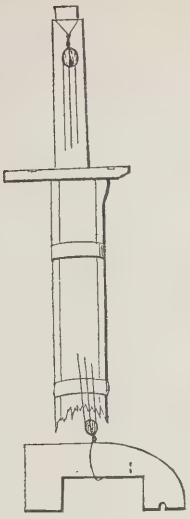
HALF-TOPS.

The following simple and beautiful method of sending up half-tops, suggested by a thorough seaman, (the late Boatswain Robert O'Neal of the navy,) is recommended as the best:

Have two stout burtons at the mast-head, (those used in getting up the tressle-trees,) and hook them to a strap through one of the futtock-holes in each half, which must be placed on deck, with the *outer* rims uppermost, at their respective sides of the mast. Sway the halves close up to the block at the mast-head and hang them there, until the cross-trees are sent aloft and bolted in their places. Then lower the halves down and secure them; sway up the upper cross-trees, and bolt and confine the whole with iron bands, sending down the burtons and girtlines, used to sway up the cross-trees. (See Fig. 11.)

* It will be observed that the figure is somewhat at variance with the absolute conditions of the case, by having the girtlines and tackle apparently on the *upper*, instead of the *under* side of the top; but this has been done designedly, that the reader might see the manner in which they were lead and secured.

Fig. 11.



## LOWER-RIGGING.

As the routine of rigging is nearly identical on all the masts, the method of one, e. g. the *fore*, will answer for a description of the others, care being taken to note the peculiarities of each as they occur. In nearly all the works on seamanship, it is recommended to shift the girtlines from the mast-head to the after-part of the tressle-trees, for the purpose of sending the shrouds aloft. But in the merchant service, where economy of time is regarded as a part and parcel of the profession, the topmast is pointed about four, or five feet above the lower mast-head, to which the eye-girtlines are attached, after the manner of a derrick. This plan is evidently preferable to that pursued by the riggers in the Navy-Yards, on account of the rapidity with which the shrouds can be got over, by saving the necessity of dipping and clearing the eye-girtline in each case. In heavy ships, however, two girtlines will be required to support the weight of the shroud, the block of the latter, or main girtline, being toggled to the *midship girtline-hole* in the top, as out of the way, and more convenient, than when secured to the after-part of the tressle-trees as directed in the books. Having done this, send hands aloft with marlinspikes, tar, slush, commander, etc. If the main-topmast and spring-stays are lead into the top, in lieu of leading directly to the deck, (as almost invariably done in the merchant service,) place the straps (fitted with clump-blocks, or thimbles and lashing-eyes, *to go forward*) over *first*,* in order to raise the eye-seizings of the under-shrouds, and to make them lay fair on the bolsters; the lower pendants having been placed, and *lashed* down, (so as not to disturb the fit of the rigging,) immediately after getting the tressle-trees aloft. Now proceed to get the shrouds

* Brady says, "*after* the second pair of shrouds," but without assigning the reason

up, and over, in the order of their succession. *Knot* the ends of the main girtline together, and fit a toggle in one part, just above. Thrust this between the two parts of the first pair of starboard-forward-shrouds, from *out, in,* somewhat more than the length of the mast-head below the eye-seizing, and put a stop around both parts to retain the toggle in its place. Stop the girtline along the shroud towards the eye, and at the *crown,* and sway aloft. When as high as the top, bend on the small girtline just below the eye-seizing, taking the end from *in, out,* (if mast-head-girtlines are used, in lieu of one on the topmast as suggested,) and stop it as in the other case. Cut the lower girtline adrift, as the shroud comes up, and steady it to the hand of the man aloft, who will bear the eye over the mast-head, and cast off the upper girtline. Place it fair on the bolster and beat it down with a wooden commander, being careful to carry the shroud well *aft,* as the angular action of the strain, in setting up, has a constant tendency to bring it forward. Turn the dead-eyes in *temporarily;* that is to say, by passing the throat-seizing only, (vide NOTE, p. 25,) and having the end stopped to the standing-part; since if the quarter and end seizings were passed, the shrouds' liability to render in the throat-seizing would be greatly increased; and send the forward port pair up in the same manner. Now rouse the legs of the shrouds well down *amidships,* i. e. in a line parallel with the mast, to give the eyes a good fit upon the bolsters, and reeve a couple of turns of the laniards, (through both *side*-holes of the dead-eyes, in order that they may not slue,) and set up all four legs at the same time by means of the pendant-tackles, so as to keep the mast upright, and the eye-seizings fair.

All the other shrouds are got over in the manner described above, starboard and port alternately, and set up temporarily like the first two pair. Shift the girtlines from the top, up to the mast-head, and lash them to the sides and well aft. Dip them down through the lubbers'-hole, and bend the starboard one to the fore-stay below the crotch, stopping it to the starboard leg; bend the port girtline on in the same manner to the port leg, and sway aloft, cutting the seizings as the legs reach the top. Pass a few turns of the lashing, (which is spliced into one of the eyes,) and either rest the collar on the lower-rigging, or hang it in a lashing from the mast-head. Send up the spring-stay in a similar manner, and dispose of it as in the other case. Now reeve the ends of the stays through the bee-sheeves, (or thimbles,) and prepare for setting up.

Hook a pendant-tackle to a couple of stout straps, one above the eyes of the rigging, and the other outside of the fore-stays on the bowsprit, with which the masts must be stayed as requisite. Fordyce has suggested that immediately succeeding the lower pendants, the *after-swifters* should be placed over, with the view of steadying the masts "gradually and accurately into their places," by means of them and the stays, "without wringing the eyes or seizings at the mast-head." This idea is certainly a good one, and little perhaps is hazarded in the assertion, that had it been adopted more universally, many of the *outré* appearances in mast-heads, arising from the absence of some such counteracting effect, might have been obviated, and more than one rigger, competent in every other respect, justly saved from the censure of those who were unable to appreciate the absolute cause.

As there are considerations of magnitude involved in the subject of staying the masts, it is thought proper to pause for the introduction of a few "rough and ready" observations, which are offered for the reader's reflection.

Confining both the architect and the sailor to their respective spheres of action,

the position, that is to say, the point in the interior of the vessel for fixing the step, is a problem, (in this *guessing* country of ours more frequently regulated by supposition than mathematics,) for the correct solution of which the former is alone responsible; while the latter, in his practical capacity at sea, becomes the instrument for testing the theoretical principles upon which the estimate is formed. Under these circumstances, designing only to treat of the subject of seamanship, (in its peculiar and limited acceptation,) it would be foreign to the purpose of the work to attempt any inculcation beyond that which falls immediately within the province of the rigger.

1. Experiment has satisfactorily proved, that by raking the masts *forward*, we increase the vessel's tendency to pitch, by changing the direction of the effort exerted by the wind on the sails, from a line parallel to one forming an oblique angle with the keel. This, of course, should be guarded against, as offering an impediment to the progressive movements of the ship, *not*, however, so much in diminishing the force of acceleration, as in augmenting the spaces over which she must pass, by causing vertical deflections from a horizontal course; besides increasing the difficulty of trimming the yards, in consequence of their confinement when *by* the wind. Indeed, the sole advantage of inclining the masts forward, consists in producing a readiness to *wear*, which, however, is always attended with a corresponding indisposition to coming to, and the obvious necessity of lee helm, to make the vessel keep to the wind. In the ordinary evolutions at sea, these objectionable causes are not always self-evident, in consequence of producing effects which are correspondingly imperceptible. But in cases of emergency; e. g. as in scudding, (where the remedy is precluded,) they are often fearfully realized; and by preserving the disposition to fall off, we increase a thousand-fold the liabilities of being brought by the lee.

2. When the masts are stayed in a *perpendicular* position with respect to the keel, the effort exerted by the wind on the sails, will be in a horizontal direction. Under these circumstances, her progressive movements will be uniform, and the resistance and velocity constant; while the objectionable features visible in the face of the preceding system, are entirely obviated, and every favorable effort communicated, which can ensure speed and safety.

Lastly; where the masts are made to rake *aft*, an increase of after-sail is thus given to the ship; as also a disposition to approach (rather than recede from) the wind; by which we obtain rapidity of movement, in the evolution of tacking. The effects produced being nearly conversely to those which are developed by raking the masts in an opposite direction, and more favorable to the sailing capacities of the ship, as we obviate to a great extent the tendency to pitch, and the difficulties of bracing.

Having stayed the masts by means of the tackle referred to, (and the swifters, if the method be adopted,) wedge them, and put on the MAST-COATS, which (according to *Glascock's* rule) are cut and made as follows, the material being either No. 1 or No. 2 canvas: "Girth the mast round at eighteen inches above the deck. Girth also round the deck at three inches from the mast-hole. These girths give the circumference at top and bottom. The length is obtained by measuring straight the distance between the places girthed. Divide the lower girths into an equal number of parts, suitably to the width of the canvas, allowing for the *seams*, which are one inch wide. The cloths must be gored upward, to produce the circumference of

the mast at the top girth ; and, when sewed together, cut with a sweep to set neatly round the mast. The upper part is then sewed into a double collar six inches wide. To find the quantity of canvas in a mast-coat, multiply the number of cloths by the length, and add the quantity in the collar."

EXAMPLE.

| | Ft. | In. | |
|---|---|---|---|
| | 1 | 8 | length. |
| | | 4 | number of cloths. |
| | 6 | 8 | |
| | 3 | 0 | feet in the collar. |
| Total | 9 | 8 | |

Turn in the dead-eyes, for a full due, by heaving the ends into their places (*inside* of the standing-part) with a strand of rope or jack-screw, and pass the quarter and end seizings. Now reeve the dead-eyes full, by the following method, which is the most economical, and always ensures a proper length : Place the coil, from which the laniards are to be cut, on deck amidships, on its edge, and take either end in each of the channels, beginning at the side-hole of the *lower* dead-eye, under the *standing*-part of the shroud, from *in, out,* and reeve the holes full ; turn a Walker's* knot into the extremity of the laniard last rove, (which will be under its proper part of the shroud, viz. the *end,* so that in setting up the running part of the laniard brings the strain on the standing-part of the shroud ;†) clap on the bight, render all parts, haul taut, and cut off from the coil as desirable. By adopting this method, a little time is saved, as two laniards can be cut and rove at the same instant from the same coil.

Now proceed to set up the lower-rigging, which should be done as follows :

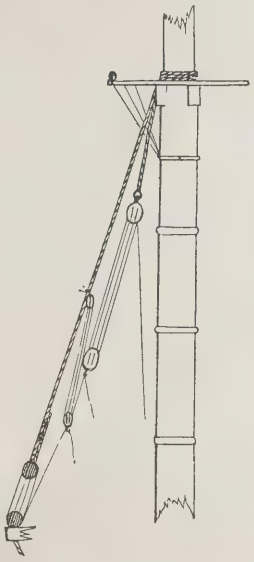
Place canvas on the shroud about halfway up, to avoid chafe, and tail the single block of a luff over it. Turn a cat's-paw into the bight of the laniard, and to a toggle thrust through, hook the lower-block, (which is double,) and lead the fall up to the pendant-tackle, as in Fig. 12. Set up all the shrouds in this manner, a pair on each side at a time for a full due, (sending down the luffs,) and secure the end of the laniard by thrusting it through the space between the dead-eye and throat-seizing, around one part of the shroud, *inside* of both, and around the other part

* The *Matthew* is omitted, as being superfluous, for when it is considered that it is the only knot in use bearing a man's name, the *surname* is sufficient for identification.

† It appears that this theory (upon the correct observance of which so much stress is laid) has in part exploded, although but recently. On board of the ship "Minesota," the opposite of the rule was observed in the fitting of the port lower-rigging, (in order to make it correspond, in appearance, with that on the starboard-side ;) and on questioning Captain A—— about the unseamanlike manner in which his laniards were rove, he replied, that "although the strain comes on the *running end* in *setting up*, yet after securing it reverts to the *standing-part*, and thus fulfils the conditions of the old rule ; *without* causing the dead-eye to slue, (as asserted by the advocates of the first method,) provided, of course, *it be turned in properly.*" The proof of this was evident, even after the vessel had performed a voyage to Liverpool and back ; for on trying the laniards, the standing-parts were taut, while the running ones were comparatively slack, and the dead-eyes perfectly square ; Glascock, Gower, Griffith, and the host of *literary* seamen, to the contrary notwithstanding.

like the first; thence back, as it came out, racking the end to the *inner* and *outer* parts. This is done to prevent the dead-eye from turning out, in case the throat-seizing should snap, and also as a support to it.

Fig. 12.



Note.—Dead-eyes are turned in as follows: Lay a strip of tarred parcelling in the score, and heave the shroud taut around the dead-eye (*with* the lay of the rope) by means of strands, (rove through the laniard-holes,) and a Spanish windlass. Reeve the first turn of the throat-seizing through the eye in the end, around both parts of the shroud, and pass the other turns, usually *nine*, from the *end* towards the standing-part, hauling them merely *hand*-taut, so that when the shroud end is turned up, all may bear equally in the strain; thence back, underneath the turns, up through the eye, and pass the riders in the cutlines of the first, securing the end (which should be whipped) around the standing-part of the shroud.

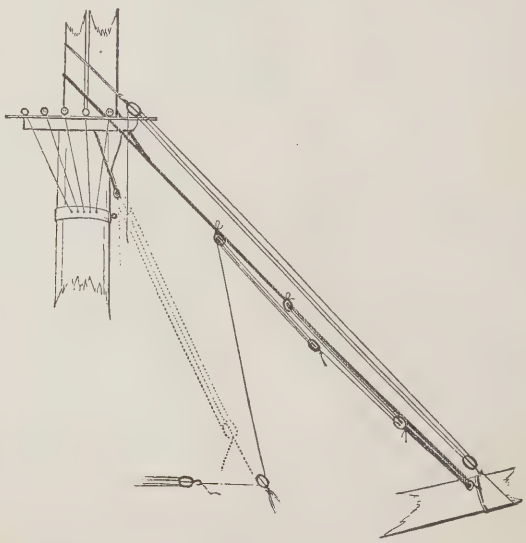
The method of "cutter-stay fashion," although still holding many *theoretical* advocates, has but few *practical* experimenters; for scarcely a ship is seen now-a-days where this method of turning in the rigging is resorted to, on account of the chafe and premature decay induced by the shortness of the nip. But Glascock says, "The more this method is tried, the more serviceable it will be found;" and cites, in proof of the assertion, "that in the heavy hurricane which the squadron of Sir Richard Strachan encountered in the late war, the *only* ships that did *not* snap the throat-seizings of the lower-rigging, draw dead-eyes, or carry away spars, were those that had their rigging turned in cutter-stay fashion."

On board of the sloop-of-war "Fairfield," fitted in the summer of 1841, the method of cutter-stay was adopted, and found to answer all the conditions perfectly. But on her arrival in the Mediterranean the rigging required turning in afresh; and on examination it was discovered that owing to the neglect of the riggers in not putting a strip of tarred canvas around the *nip*, a very considerable chafe had been made, which rendered the turning up of the ends necessary, although, in justice to

the system of cutter-stay, it should be added, that the present method was substituted on that account *only*.

Having secured the masts in the desired position, proceed to set up the stays by the following method, observing, first, to let the collars down snugly over the eyes of the lower-rigging, and to pass the remaining turns of the eye-lashing,—*not*, however, so as to bring the legs "eye and eye," as the stay can be set up afterwards *aloft*, (if the amount required be but slight,) without the trouble of casting off the seizings, and working on the reeving end.

Fig. 13.



At the distance of eight or ten feet up the stay, clap on the single-block of a luff-tackle, (having canvas underneath to protect it from chafe,) and hook the lower one to a strap around the end of the stay, rove from *forward, aft*, through the thimble, (this supposes straps to be used.) Then to a backwall* in the hauling part, which leads upward, hook the *single* block of another luff, (the double one of which is tailed on to the stay higher up,) and lead the fall of this last-mentioned luff, down through a single-block on the bowsprit, in a line with the stay, and hook in a deck-purchase, or use the pendant-tackle, as illustrated in Fig. 13. Having got the stays taut, (which will be the case when they form a *straight* line,) pass the seizings, (like those used in forming the eye of a shroud,) and take off the luffs.

Now seize on the sheer-poles with a cross-seizing, to keep the dead-eyes from slueing, (on account of the tendency to unlay in the shrouds,) having a strip of tarred canvas, or (which looks neater) leather underneath, to prevent chafe, and prepare to rattle down. Or, should the old custom of futtock-staffs on the legs of the lower-rigging be still adhered to, (which, by-the-by, is an abominable antiquity,) swifter in the shroud-legs, by girting them, towards each other, with a piece of small stuff, but not *too* much, lest the seizings of the ratlins should part when let go; and seize the staffs, on *outside*, to all except the swifters, with their shrouds

* Brady calls it a "*blackwall.*"

and the cat-harpen legs, (the latter secured with cross-lashings, in the wake of each shroud and the staff,) the distance of half the width of the after-part of the top from the eye-seizing down. This system has, however, fallen into disuse; a far better and neater plan is to have iron rods, or rope legs, from a spider-band around the mast, below the hounds, to the plates in the top rim, setting up, in the former case, with turn-buckles or screws; and in the latter, with a lashing, by means of a Spanish windlass or tackle, to the deck. This method is infinitely preferable to the one for which it is substituted; since, if the lower rigging becomes slack, the dead-eyes of the topmast rigging still remain fixed and stationary, which, in point of security, is a consideration of some magnitude.

Hook the futtock-shrouds to the plates in the top, observing to have the points of the hooks *in-board*, so that the bights of ropes from aloft, as studding-sail tacks, &c., are not in danger of being caught over them; and then proceed to rattle down, first lashing oars or spars athwart the rigging, at the distance of four or five feet apart, for the men to stand on while at work.* The ratlins are usually of eighteen-thread stuff, fitted with a small, neat, spliced eye, (thrust once and a half,) which is seized on to the shroud with marline, (or, which is neater still, a rope-yarn, twisted up the opposite way, and rubbed smooth,) at the distance of fifteen or sixteen inches below the preceding one. A clove-hitch is then formed *outside*, around the next leg, with a marlinspike, and the ratlin hove taut. In this manner it is made to reach the after-shroud, and then seized on as at the commencement; every fifth or "sheer" ratlin being extended to the swifters, which, with these exceptions, are omitted.

An exceedingly simple *ruse*, (although perhaps unworthy a significant reference here,) where the ratlin is too long to be seized on thus, and yet not sufficiently so to allow a new eye to be formed, is to heave turns in with the lay of the stuff, until shortened up as much as required. This is vulgarly defined, by the *non leges scriptæ* of nautical phraseology, an "Irish splice;" and notwithstanding its simplicity, is quite worthy of a stowage among the "wrinkles" of one's professional knowledge.

Now unreeve the girts employed in swiftering in, and black the rigging.† After which, send down the spars, and square and cap the ends.

NOTE.—The "full due" referred to in the preceding paragraphs is by no means intended as the only, or final setting up the rigging is to receive in the vessel's outfit.

* Prior to ratling down the rigging, a line parallel to that of the vessel's floatation should be drawn across the shroud-legs, (on both sides,) through the points where it is intended to seize on the lower ratlins, in order to have them correspond with her "sit" upon the water. And if these marks be continued upward to the tressle-trees, at a distance apart varying from fourteen to sixteen inches, as the rigger may choose, (that being the extreme separation,) the work can be greatly facilitated by commencing with three or four ends of the ratling stuff at the same time, in as many different places on the rigging, and without the necessity of referring constantly to the "measuring stick."

Nothing is here said of *neatness* in this particular, as it is supposed to be a consideration sufficiently regarded by every rigger; since no neglect is so palpable, even to the eye of the most inexperienced, as that of ratling down the rigging in a careless and slovenly manner.

† Various compositions have been used for this purpose. *Glascock* recommends "Stockholm tar, with a certain portion of salt-water, boiled together—and put on *hot*." *Fordyce* says, "Stockholm tar, coal-tar, and salt-water in equal proportions, heated up in a fish-kettle." *Brady* suggests the following. "To half a barrel of tar, add six gallons of whiskey, four pounds of litharge, four pounds of lampblack, two buckets of boiling beef-pickle, or hot salt-water; mix well together and apply immediately."

The season of the year—the length of time in port, and the celerity, or tardiness of equipment, are all circumstances which either make it necessary to give the rigging other *pulls*, or to afford opportunities for doing so. *Fordyce*, thus states the criterion of the British service :

"Forty-eight hours, or so, after placing, setting up, and swiftering in the rigging, if the weather be favorable, get another pull of it, and mark off for squaring.

"Five or six days after this, get a third pull, turning in the dead-eyes, with their proper seizings to the squaring marks, and bringing them down for good and all. Rattle down the rigging.

"Square off and point, or cap, (with canvas or leather,) the ends of the shrouds, and point, or whip the ends of the laniards.

"Another, or fourth pull of the rigging, (supposing it to be new,) a fortnight or so after the third, will amply prepare it for sea, if the weather prove favorable."

This system may answer very well for Navy Yards, where time is not considered, but it is totally incompatible with the enterprise and dispatch characteristic of the American mercantile marine. In that branch of the service, two settings up are generally given at first, and when every thing is *a taunto*, just before going to sea, it is usual to get a pull of the laniards and to square the ratlins, etc.

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The routine of rigging embraced in the foregoing article refers exclusively to the foremast : yet the difference in the other masts is so immaterial that it is only necessary to allude to a few peculiarities. Over the mainmast-head, no clump-blocks and straps are placed, and the mizen lower-pendant, which is single, is fitted with a cut-splice, while the odd shrouds (although disapproved of by seamen generally) are fitted with horse-shoe eyes. In vessels of war the starboard main-stay should be passed *over and under* the bitts in setting up, and the port one *vice versa*. This *ruse* will greatly diminish the chances of losing both by a single shot in the event of action.

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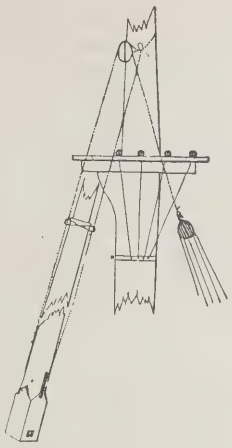
## TOPMASTS.

The operation of getting in topmasts, in lieu of being confined to one particular method, is performed differently by almost every rigger. But the established limits of the work preclude the introduction of more than one, and render it necessary on our part, to make what might be *critically* termed an "invidious distinction." The following method, adopted by an officer of the navy, whose abilities as a seaman are well known to the service, is selected, on account of its perfect feasibility under all circumstances, as the best and simplest. Acting upon the supposition, assumed in the routine of rigging explained in the foregoing pages, that the ship is moored in the stream, tow the mast alongside with the *head* forward,* having pre-

* Captain ——— recommends in all cases of getting spars on board while in the stream, (where there is a *tide*-way,) to tow them alongside in the reverse manner—a topmast, for example, with the *heel* forward, &c.; then by letting the foremast end be swept aft by the current during the operation of swaying it on board, there will be no necessity for a hauling-guy to rouse the heel forward *against* the tide.

viously secured a large bull's-eye, or single block, to the hounds on each side, in the same plane with the lower sheeve-hole.

Fig. 14.



Hitch the end of a hawser at the mast-head, above the eyes of the rigging, (*outside* and clear of the top,) and reeve the other through one of the bull's-eyes, (or blocks,) and the sheeve-hole; thence up through the opposite bull's-eye, and a block lashed at the mast-head, (again *outside* of the top,) as in Fig. 14; leading it to the deck, and clapping on a pendant-tackle. With this purchase, and by means of easing-guys and jiggers, sway the mast in-board, and up and down the lower-mast; lashing the head to the crotch of the fore-stay collar,* and resting the heel on deck, in order to shift the mast-head-block, and standing-part of hawser lower down, to lead through the lubber's-hole. Remove the deck scuttle—cast off the stay-lashing, and lower the mast, until clear of the top rim; then sway it up, and point it through the tressle-trees and round-hole of lower cap; which latter is sent up "before all," with the girtlines immediately after rigging the lower-mast, by bending them on through the round-hole, and stopping them along to the after-part, observing to keep the bolts *uppermost*, so that they do not come in contact with the top-rim, &c., in the cap's passage aloft. Reeve a stout strap through the fid-hole, to which, hook both the pendant-tackles; take off the bull's-eyes (or blocks) at the hounds, and mast-head—unreeve the hawser, and prepare for shipping the CAP, which is done as follows: Pass secure lashings through the eye-bolts, over the top-mast-head, (or *wedge* the cap,) and sway up on the pendant-tackles, until clear of the tenon of the lower-mast; then slue the heel of the topmast, by means of guys bent to the extremities of a long heaver placed in the fid-hole, until the cap is fair for shipping. White-lead the tenon and mortice; send up the cap-shore,† (to

* Supposing it to be the fore-topmast.

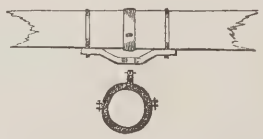
† Cap-shores in the merchant service are now seldom if ever met with; the necessity of them being obviated in a great measure by the shortness of the cap, forward. But this *economical* dispensation is frequently attended with an expenditure of time and labor, in striking topmasts, on account of the weight of the spars and rigging bringing a heavy strain on the fore-part of the cap, 'which," as Glascock justly observes, "causes it to droop and bind the mast."

which a laniard should be attached for the purpose of securing it aloft,) and lower away, beating the cap down in its place, and tacking a piece of sheet-lead over as a protection from the weather.

Cast off the lashings, (or remove the wedges,) and sway the topmast-head a few feet above the cap. Lash a couple of stout burton-blocks to the tenon, (having the falls rove,) which should be sent down "behind all" for the cross-trees, (placed on deck *well* abaft the mast.) Secure the lower blocks to each after-horn of the tressle-trees on the *upper* side, and stop the standing-parts along to the forward-horns, in the same manner as that resorted to in sending up the lower tressle-trees; having a guy from the mainmast-head, (if the fore-topmast cross-trees,) to keep them clear of the top in going aloft. Sway up on the burtons, bear off, cut the stops as necessary, and land them on the lower cap, where they should be securely lashed—having the forward part inclined upward, with the chock resting against the topmast. Cast off the burtons—remove the blocks from the tenon—or, if girtlines are used to get the cross-trees aloft, (as is sometimes done,) shift them at once to the middle-horns, ready for the rigging—white-lead all parts in the wake of each other, and lower away on the pendant-tackles, until the cross-trees come fair over the mast-head, cutting them forward, or aft, as may be necessary.

Of late years a new parrel has been introduced in the merchant-service, which causes a slight deviation in the routine of rigging, on account of its going *over* the topmast-head *prior* to the cross-trees, in order to avoid the difficulties, which would be otherwise experienced by the coopers and blacksmiths in completing it, if left until afterwards.

Fig. 15.



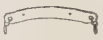
This parrel consists of a number of stout staves, forming a circle, (somewhat larger in diameter than the topmast,) confined by a broad iron spider-band, having a neck, or shoulder, which connects with a truss on the topsail-yard, by means of a key, as in Fig. 15. They were used on board of the store-ship "Southampton," in 1846; and although she encountered a series of heavy gales, on her return from the coast of Africa, after an absence of nearly two years, no accident happened to the yards whatever. The advantages which this parrel possesses over all the others, viz.: of keeping the yard clear of the rigging, and the facility of clewing down quickly, have been deemed sufficient to warrant an almost universal adoption of it, in the mercantile marine. It is perhaps well, however, to remark, that in order to check the play of the parrel, (which would otherwise follow,) the diameter of the topmast should not vary from the cap to the hounds.

Now sway up, and lodge the cross-trees on the hounds of the topmast, prying up the after-end, and beating them down in their places. Hook the top-blocks,*

* The manner of doing which has always been a favorite "catch question" with the *saline* sages of the forecastle in their teachings of the "green 'uns;" on account of the emphatic "from forward, aft, *of course*," invariably returned to the query, or the equally prompt conjectural vice-versa, "*to be sure.*" Neither of which is right—the block being hooked from *in, out, necessarily.*

and reeve the pendants, by passing each pointed end through its respective block, and sheeve in the heel, and clinching it *over the cap* on the opposite side, and *not* "to the eye-bolts;" after which, hook the top-tackles to the other ends, (fitted with thimbles,) and remove the fid-strap and pendant-tackles used in pointing the topmast. Attach a girtline-block (vide page 30) to each (*middle* if three, otherwise) after-horn of the cross-trees, and prepare for rigging. Send up and lash the bolsters, well protected with tarred parcelling, and bolt the *gin-bar* down securely in its place. This is a late invention, and in addition to its perfect security, tends much to the neat appearance of the mast-head, by dispensing with the huge strap and pendant for gins and burtons, formerly in use. It consists of a short, stout bar of iron, placed across the topmast tressle-trees, between the "doublings" of the top-gallant-mast, with links for the gin-blocks. The burton-pendant (now unknown in the merchant service) being fitted with a hook in the upper end, which connects to an eye-bolt on the *under* side of the tressle-trees. This plan was adopted on board of the "Columbus," 74, while flag-ship of the East India squadron.

Fig. 16.



Objections are frequently made by seamen to rigging the topmasts before fidding, on account of the increased weight thereby brought upon the top-pendants, which (considering the advantages of safety, and a top unincumbered with rope) are not without some shadow of reason; and since it is usual to fid the mast first, in order to ascertain its fit, etc. before rigging, the method should be adopted. Having then fidded the topmast, proceed to get the shrouds and backstays up and over, in the following order, after the manner employed in Lower-Rigging, observing to have an eye-girtline at the tenon:

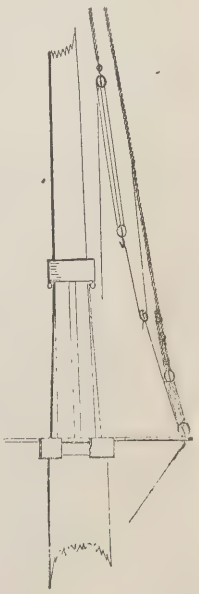
*First.* Starboard and port shrouds alternately—the odd ones being fitted with horse-shoe eyes.

*Second.* Standing backstays.

*Third.* Fore-and-aft stays.

*Lastly.* Breast-backstays, fitted with a neat eye, through which a *hide* grommet is formed above the eyes of the rigging, or a strap and toggle passed as recommended on page 12. Finally, send up the jib-stay, (if the boom be rigged out at the same time,) and reeve the topmast-stays through the bees on the bowsprit, clapping luffs on them, to give the mast the proper stay. Then proceed to set up the rigging by means of a runner and burton fitted as follows.

Fig. 17.



The runner (which has a thimble in one end) being rove through a single block, hooked to a cat's-paw in the laniard, is tailed on to the shroud-leg about six or eight feet above, and the lower block of the top-burton then hooked to the thimble, as in the annexed figure. Having set up the shrouds by means of this purchase in a manner precisely similar to that adopted in the case of the lower-rigging, turn the dead-eyes in to the standing backstays and set them up also. Lash on the sheer-poles and futtock-staffs*—the latter *inside* of the topmast

* Which should be well parcelled and served, in order not to chafe the top-gallant rigging, as they are only used for it to lead over, in its course to the top.

shrouds, and swifter in. Seize the forward cat-harpen legs* (on each side) to the forward shrouds, and the after ones (around the mast) to the after shrouds—then spar, and rattle down, and cap, and square the rigging, As a *finale*, reeve and fit the netting on the top-railing, and sway aloft the upper cap, which should be placed in the fore part of the topmast cross-trees ready for shipping. Lastly, send down the girtlines from the tenon and horns, used in getting the rigging over.

Note.—Both futtock-staffs, and cat-harpen legs have disappeared from the merchant service. The top-gallant shrouds setting up through bull's-eyes at the horns of the cross-trees, which are retained by iron legs, with screws or turnbuckles, to a band just below the hounds of the topmast, like the futtocks of the lower-rigging.

N. B.—In many merchant vessels, and particularly those of small tonnage, the topmast rigging is simply rove through large bull's-eyes, instead of being turned in with dead-eyes and laniards. And frequently, after the lower and topmasts are rigged, a tarpaulin coat fitting snugly, is placed over the eyes of the rigging, as a protection from dampness and wet. This answers very well, and if painted white, does not detract from the neat appearance of the mast-head.

## JIB-BOOM.

Almost every rigger has a particular method of getting this spar on board. *Brady* recommends using "the hawser, or tackle, which was left at the foremast-head, when getting on board the fore-topmast." *Totten* suggests hoisting it up "by one of the pendant-tackles, with the outer end forward;" while others employ "a purchase on the fore-topmast backstay." But the following method, adopted by the late Boatswain O'Neal, (and somewhat more explicit than either of the above,) in refitting the frigate "Cumberland," is thought to be the best.

Bring the boom alongside with the head forward, and reeve a spare piece of rope, (studding-sail halliards if at hand,) through the sheeve-holes in each end, a sufficient number of times, and make it fast. Overhaul down the main pendant-tackle, and hook it into a cuckold's-neck formed in the bight of the span, having the boom to hang slightly *heel* heavy. Sway it up, bearing it clear of the ship's side—ease it in-board, and land it in the gangway; unreeve the span, and carry the boom forward, pointing it through the bowsprit-cap, and reeve the heel-rope, which is done as follows: Pass one end through a single-block, hooked to an eye-bolt on one side of the bowsprit-cap; thence through the sheeve in the heel, and clinch it to the other bolt, on the opposite side of the cap. Man the heel-rope, and rig the boom out, until the shoulders are just forward of the bowsprit end; then tar them in wake of the rigging, and get over the *foot-ropes first*,† which are fitted with neat spliced eyes, in the outer ends, (thrust once and a half,) and wormed and served.‡

*"They should be fitted short enough to admit of being frequently set up, before they become so much stretched as to make it necessary to send them down to alter."

† This is done, in order that the men employed in fitting or stripping ship, may have something to stand on, while placing, or removing the other rigging.

‡ This plan is preferable to the "cut-splice," which is rendered round the boom by the weight of the men, first on one side and then the other—a circumstance inducing chafe, and causing the splices to be forever "*lop-sided*."

The strands are then unlayed, up to the service, and Walker's knots worked in at equal distances, (to keep the men from slipping, on account of the steeve of the boom;) after which, the rope is again laid up, and the inner ends formed into artificial eyes, which are seized to bolts in the bowsprit-cap. Thus fitted, they should be long enough to allow the men who go out on the boom, to stand with the lower part of their breasts against it. Next put over the *jib-guys* fitted with a "cut-eye," formed by seizings on each side, and covered with canvas. Lastly, put over the eye of the *martingale-stay*, made in the same manner as those for the foot-ropes. Reeve the jib-stay through the hanks and the inner sheeve-hole of the boom-end; and sway the dolphin-striker up by means of a tackle from the bowsprit-cap, hooking it to its respective eye-bolt, and putting over the lower eye of martingale-stay, and the gob-lines, fitted with a round-eye in one end, and a hook-thimble in the other, which latter, connects with a bolt on each side of the cutwater. Finally, ship the wythe for the flying-jib-boom: man the heel-rope, and rig out, placing the heel in the saddle, and clamping it. Pass the belly-lashing, set up the jib, and martingale-stays, seize the top-gallant bowline-blocks to the jib-guys, (far enough out from the shoulders to allow the flying-jib-boom to pass clear,) and unreeve the heel-rope.

Note.—On board of merchant vessels an iron band is placed around the shoulders of the jib-boom, having an eye-bolt on each side for the guys and foot-ropes, (fitted with hook-thimbles,) and one on the under side for the martingale, which connects with a hook also. The gob-lines and martingale, which are made of chain, connect to the dolphin-striker in a similar manner.

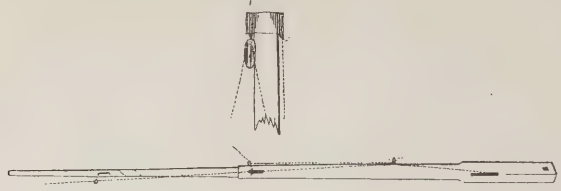
## TOP-GALLANT-MASTS.

Lash the jack-block aloft above the eyes of the topmast rigging, and reeve the top-gallant-mast rope: first through the block, then the square hole in the cross-trees, and lastly the lizard (see Fig. 18) at the royal-mast-head, and the sheeve in the heel, seizing it to the hounds of the top-gallant-mast, and leaving end enough over to clinch to the eye-bolt in the upper cap, (when shipped,) before fidding. Send the hauling-part down through the cross-trees and lubber's-hole to the deck, and rack both parts of the mast-rope securely together just above the lower sheeve-hole, and sway aloft, bending a tripping-line on through the fid-hole to guy the mast clear in its passage up. Point the head of the royal-mast through the cross-trees—take off the lizard, (which is now of no further use,) and prepare for shipping the upper cap. Sway the mast up through the latter—placed *above* the collars of the stays, and secure it to the hounds of the royal-mast by means of wedges and lashings. Send aloft the cap-shore—sway higher, and proceed after the manner directed in shipping the lower cap, (page 29.)

Remove the lashing and wedges, and clinch the end of the mast-rope to the eye-bolt in the cap, slacking down the former, (kept from rendering by the rackings,) in order to take the strain from the jack-block, which must now be unlashed and hooked to its proper eye-bolt also: after which, cut the racking and the seizing at the hounds,

letting the mast hang by the mast-rope, the end of which is belayed on deck. Lash a stout girtline-block to the cap, and overhaul the line down abaft all, for the jack

Fig. 18.



and funnel,* which should be placed on deck, with the rigging over in the following order, the eyes being made to fit the cylinder exactly, and covered with canvas :†

*First.* Fore-and-aft stay.
*Second.* Shrouds.
*Third.* Backstays.
*Lastly.* Breast-backstays, (over the *fore*, last of all, flying-jib stay.)

Bend the girtline to the rigging around all parts, the length of the *topmast*-head below the jack, and put a good stop through the cylinder, sending it aloft, with a guy attached, to keep it clear. Cut the stop when high enough, and place the jack over the cap, assisting to do so, if necessary, with a rope's end through the royal sheeve-hole. Now lower the top-gallant-mast, cutting the cylinder forward, until it is fair over the hole, and lash it, for fear of accident. Reeve the top-gallant-shrouds through the horns of the cross-trees, (or bull's-eyes, if in the merchant service,) and place the royal-rigging (sent up by the girtline also) over the funnel. Sway up on the mast-rope—point the royal-mast-head through—ship the truck, (with signal halliards rove, spindle and conductor‡ attached,) and fit the *royal-stay*

* The rim of which should be rounded off, or filled in with lead, and a circular piece of canvas placed over to prevent chafe.

† The exclusion of odd shrouds and breast-backstays from the top-gallant-masts in the merchant service, renders the funnel here referred to *dispensable*—a single grommet being used instead. This, however, is generally fitted with a small becket, or thimble, on each side, (a little forward of the centre,) for the top-gallant-lifts to seize to, which are made to go *standing*, of just sufficient length to allow the yard to hang clear of the upper cap when clewed down. (Vide Top-gallant-Yards.)

‡ It is a matter of no little surprise that so many vessels, in the merchant service, are equipped without this most *necessary* appendage; and that even those used in the navy are little else than *nominal* conductors, put up apparently in view of keeping within the pale of some *expiring* regulation. A great number of the vessels, from which no accounts have ever been received, have doubtless been lost *solely*, in consequence of not being properly protected against the effects of *lightning*. That imperfect building, or deficient navigation, are the causes of all the calamities at sea, no one who is acquainted with the characteristics of the American mercantile marine, will attempt to maintain for an instant; or that all of those whose names are written in the dark and mysterious calendar of "lost at sea," have *necessarily* gone down in "tempest-tossed" and foundering ships. The effects of lightning, as witnessed on shore, are often dreadful indeed, but when the horrors of a conflagration at sea are superadded, without the hope of escape, or rescue, no pen can portray the agony of such a scene; and it seems almost madness to neglect the *only* means of guarding a ship against an element so fickle, and yet withal so fatal in its effects and consequences.

Some years since a lightning conductor was invented by Capt. Harris of the British Navy, and subsequently adopted throughout that service. This consists of a continuous line of double plates of

down on the hounds, (above which a grommet* is sometimes worked ;) then the *shrouds*, and lastly, the *backstays*. Reeve the shrouds through the jacks, the backstays to the top and channels, and the fore-and-aft stays forward, through single blocks at the jib-boom end, (if the flying-jib-boom should not be rigged out, at the same time.) Cast off the funnel-lashing from the cap—man the mast-rope—unbend the tripping-line—sway up, and fid, setting up the rigging, *temporarily*, to steady and secure the mast.

## FLYING-JIB-BOOM.

Sway it on board, either by means of a bill-tackle on the topmast-backstay, or use the span, as directed under the head of JIB-BOOM, and get it ready for going out. Lash a single block to the jib-stay, (and *not* "to the wythe," as sometimes directed, for if so, the boom cannot be rigged out at all,) through which reeve the heel-rope, taking a hitch with the end over the heel of the boom, and clapping stops around both, to the shoulders. Pass *slip*-ropes also over the jib, and flying-jib-boom, (to hold the latter up, in its passage out,) and rouse on the heel-rope, pointing the end of the boom through the wythe, until the shoulders are clear of the jib-boom end. Tar them in the wake of the rigging, and put over a *grommet*, with thimbles on each side, for the royal-bowlines. Next, the *foot-ropes*, (fitted like those for the jib-boom,) and seize the inner eyes to the jib-guys ; then the *flying-jib guys*, and lastly, the *martingale-stay*, which reeves *through* the dolphin-striker, and leads to the head. Reeve the flying-jib, and fore-royal-stays, (passing the former through the hanks ;†) cut the stops ; rig out, and pass the heel and belly lashings. Set up the martingale, and flying-jib-stays—take off the heel-rope—set up the royal shrouds and backstays, and finally, the fore-and-aft stays, for a full-due.

NOTE.—In the merchant service, the martingale-stay is frequently of chain, reaching only to the dolphin-striker, where it is secured by means of a hook to an iron

*copper* (38 oz. per square foot) let into a groove on the after part of the masts, and extending from the truck-spindle to the lower cap, gradually increasing in width from two and a half to four inches. At the cap, the conductor meets a similar line of metal, running entirely through the centre of the lower mast, which is stepped upon a broad plate of copper on the kelson—from whence the fluid is discharged by means of bolts of copper running through and through at each extremity of the plate. The advantage of this method consists in the fact of its being a better conductor of lightning than iron in the ratio of 6 to 1 ; and by being made of *plates*, in lieu of rods or links, it exposes *four* surfaces to the action of the fluid, besides imparting to the lighter and loftier masts a very considerable degree of support. When we consider that not a single war-vessel in this country is fitted with one of these conductors, it amounts almost to a stigma upon the American navy.

In reference to the merchant service, it would seem that the story of the ill-fated "Logan," as detailed in the "History of Remarkable Shipwrecks," has failed to awaken attention to this subject ; and since the *moral* of a hundred tales equally frightful cannot, or *will* not be appreciated, it would not only be a *judicious* adoption, on the part of *insurance companies*, but a *philanthropic* one also, were they to compel *every* ship to be fitted with *some* means of guarding her against this chance of loss.

* In the merchant service this grommet is fitted with beckets, or thimbles, for the royal lifts

† Vide BENDING SAILS.

band with eye-bolts; and the foot-ropes and guys fitted with hook-thimbles in the outer ends, which connect to the shoulder-band in a similar manner.

On board of the frigate "Cumberland," in lieu of a grommet and thimbles, for the royal-bowlines, small bull's-eyes were seized to the guys for that purpose; and in rigging ship, the royal shrouds and backstays were set up *first*, because the weight of the stays alone brought the mast forward too much.

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## TOPSAIL-YARDS.

All the *writers* on seamanship, place topsail-yards next in order after lower ones, in rigging ship; but this routine is not *always* observed in practice, and particularly where expedition is required in the equipment, on account of the increased labor and difficulty of crossing, if the lower yard is rigged and sent up first. This consideration, although apparently a slight one in the abstract, nevertheless becomes of some magnitude in the practical application of this *ci-devant* rule. Having towed the yard off to the ship, (supposing her to be in the stream,) say on the port side with the starboard yard-arm forward,* lash a large single-block at the topmast-head, having a strap sufficiently long to permit it to hang clear of the tressle-trees. Through this reeve a hawser down, (outside of all,) and bend it on to the slings of the yard, either stopping it to the forward (in this case starboard) quarter, with stout seizings, or use a lizard, and secure the ship's side from chafe by fenders and skids. Hook the port pendant-tackle, also, to a strap on the after-quarter, and man it with the hawser, (taken to the capstan,) swaying the yard on board, which must be kept from canting aft against the mast, by means of a purchase, or guy, leading from forward. Ease the lizard (or stops) as necessary—sway on the pendant-tackle, until clear of the ship's side, and lower away, landing the yard as you had it alongside, (viz. with the starboard yard-arm forward,) in the port gangway, on chocks, which should also be placed underneath the *inner* quarters, to keep the yard from becoming bowed in the slings through its own weight. Now cast off the hawser and tackle; tar the yard-arms, and prepare for rigging.

1. Tye-blocks.—Although invariably iron-strapped, and connected by means of a bolt to a band going around the slings, (after the yard is crossed,) it is thought proper to describe the manner of securing the block, when fitted in the old-fashioned way; as the present method, though by far the best and neatest, is nevertheless not entirely free from accident. Having leathered the slings, find the exact centre of the yard,† and heave the block into the strap, (formed of a long and short grommet, wormed, parcelled, and served,) with a strand and Spanish windlass, and seize it *loosely;* after which, lash it on the yard with the breech fitting down snugly, and the sheeve standing fore and aft, passing the rose-seizing, connecting the

* Vide note, page 28, in reference to getting spars on board.

† Where two tyes are used, as on board of heavy ships, the blocks are separated from each other by a space equal to the diameter of the topmast.

eye of the long grommet (going around the yard) to that of the short one, on the forward side, underneath. N. B.—On board of many merchant-men (of small tonnage) this block is dispensed with, and the tye hooked to an eye-bolt in the sling-band.

2. PARREL.—If the newly-invented parrel, described under the head of TOPMASTS, should not be adopted, prepare to lash the rope one (fitted as follows) on to the yard. This consists of a long and short leg, marled together and leathered, of sufficient length to go around the mast and yard on each side. An eye, which is wormed, parcelled, and served, is spliced in the ends of the two legs, and stout quarter-seizings put on both, close to the eyes of the short leg. The long one is then passed around the quarter of the yard, just half the diameter of the topmast from the centre, and secured to the short one by a rose-seizing on the *upper* forward side. When the yard is crossed, the remaining leg is passed on the opposite side, and secured in the same manner.

In many instances in the merchant service, *jaws* with a simple lashing abaft the mast have been substituted for both the parrels here alluded to, and are preferred by many seamen on account of their cheapness and durability.

3. QUARTER-BLOCKS should always be iron strapped, on account of the facility with which the yards can be shifted, without the necessity of unreeving sheets and clew-lines. This plan has been universally adopted in the merchant service;* but it is a subject of regret, that a method tending so much to rapidity of movement, in the frequent and *necessary* evolution of shifting yards, should not have found its way into the navy long ere this. When the old plan of rope is resorted to, they are fitted with single straps, which are served—the *after* part only being leathered, to prevent chafe, and secured to the yard by a rose-seizing on top, having a span-lashing underneath, to keep them from spreading.

4. STRAPS AND THIMBLES, (fitted with small eyes,) for standing-parts of topsail clew-lines. These are simply served and secured to the yard on top, (close to the quarter-blocks,) with rose-seizings.

5. ROLLING-TACKLE AND BURTON-STRAPS.†—These are formed of grommets, doubled, (*not double-grommets,*) and thimbles‡—served and secured with rose-seizings on the forward side—the former, about one-third the length of the yard-arm out from the slings, and the latter just inside of the sheeve-holes.

6. HEAD EARING STRAPS AND THIMBLES.—These are fitted in a variety of ways—sometimes of *sennet,* and nailed around the yard, as done on board of the frigate

* The quarter-blocks on board of merchant vessels are *threefold,* in order to receive the reef-tackle, which comes in along the yard underneath, in lieu of reeving through the outer sheeve to the burton, as done in the navy. This is a good plan, as it serves the purpose of a downhaul-tackle in clewing down.

† These are frequently omitted in the merchant service. The former, particularly on board of those vessels fitted with the new-fashioned parrel, which, in a measure, does away with the necessity of rolling-tackles, on account of the little play given to the yard. The latter is dispensed with, for "*causes unknown.*"

‡ The reason is obvious—for, in the event of parting the strap, it could be replaced without disturbing any of the other rigging, which would be impossible with a simple grommet going *over* the yard

"United States" in 1846; or *in one* with the eyes of the jack-stays and foot-ropes, as in the "Cumberland" during her late cruise in the Mediterranean. And again, in the merchant service, a simple eye-bolt in the shoulder-band of the yard is made to answer the purpose. The first method is preferable on account of forming a "soft bed" for the foot-ropes. The second for neatness—although there is a sacrifice of security, which is hardly commendable; while the third has advantages over both in point of strength.

NOTE.—This routine of rigging may be objected to by the sailors of "auld lang syne," as reversing somewhat the "ancient order;" but it would be well to remember that unless the strap for the head-earing be put over the yard-arm *first*, it will not only chafe the jack-stay, but *necessarily* every thing else *inside* of it.

7. JACK-STAYS.—Wood and iron are used throughout the merchant service; but where rope is preferred, they are served the whole length, and fitted to go over the yard-arms with eyes; after which, they are rove through staples on the upper forward side, (being protected from chafe by strips of leather,*) and set up to each other in the slings, by means of small eye-lashings.

8. FOOT-ROPES.—These are fitted with an eye, going over the yard-arm abaft, which is merely wormed, and the splice served. They are then rove through the stirrups,† and the ends (which are served as far out as they are liable to chafe from the topmast rigging) taken abaft the mast, (*when the yard is crossed,*) and secured to the opposite quarters on *top*, by means of an eye-lashing, passed over the yard—round on the forward side—underneath, up, and back through the eye again, a sufficient number of times; after which, two half-hitches are taken around all parts to secure the end. This plan of leading them is recommended, on account of the facility with which the men can get on and off the yard. In merchant vessels, and on board of the store-ships, the foot-ropes are fitted with a hook, which connects to an eye-bolt on the after-side of the shoulder-band.

9. BRACE-BLOCKS.—These are fitted variously. In the merchant service they are attached to the shoulder-band on the yard, by means of a hook-thimble seized into the strap of the block. But in the navy two straps are used, connected with lock-thimbles, and fitted as follows. The *yard-strap*, into which one thimble is seized, consists of a grommet, wormed and covered with canvas, and fitting so snugly as to require to be driven on. The *block-strap* (a double one) is cut the necessary length—the ends spliced together, and then wormed and covered with canvas. After which, the bight is thrust through the other thimble, and both parts passed around the block, which is secured into the strap by a round seizing, between the breech and thimble.

10. LIFTS.—In large vessels, as ships-of-the-line, they are fitted double, reeving through a block over the yard-arm next after the brace; but in the smaller vessels of the naval service, they are formed with a simple eye, which, with the splice, is

* In rigging, as little leather as possible should be used, on account of its tendency to produce rot; just sufficient to guard against chafe, being deemed by men of experience a judicious use.

† Which are formed with thimbles in the lower ends, and small artificial eyes in the upper ones, seized to the jack-stay staples.

wormed and covered with canvas; while those for merchant ships are fitted with a hook-thimble to the shoulder-band.

11. Flemish-horses.—These are spliced around a thimble on the pacific-iron for that purpose, and the eye in the other end secured on top of the yard to the jack-stay, the length of the shoulder inside of the sheeve-hole, with a rose-seizing.

12. Jewel-blocks, which are single and rope-strapped, are sometimes secured to a thimble around the pacific-iron, outside of that for the flemish-horse, and frequently fitted to go *over* the yard-arm; but the best plan (as it admits of their being taken off at all times without difficulty) is to connect them to the pacific-iron with sister-hooks.

13. Tyes.—Where rope is used, (which, by-the-by, is not the case in the merchant service, chain being universally adopted,) they should be fitted of sufficient length to admit of sending the yard up and down with them—stopping the surplus end of the standing-part, (which is secured at the mast-head, "breeching-fashion," with two stout seizings,) down the forward-swifter of the topmast-rigging. This plan is also recommended by Glascock and others, for vessels of war; as it saves both time and trouble in "shifting," and the end serves to sling the yard with, in the event of action.

Lastly. See that the armorers and carpenters have prepared the yard, by attaching the boom-irons, reefing-cleats, bolsters (inside of sheeve-hole) for top-gallant-sheets, etc., and prepare for crossing.

As on all nice points of seamanship, there are many opinions in reference to sending up topsail-yards; but the following method, attested by practice, and combining as it were the commendable features of almost every other system, is selected as the best: Reeve the hawser, used in getting the yard on board, through the thimble of a stout lizard, (secured in the starboard rolling-tackle strap,) and a large single block lashed on top of the yard, the diameter of the topmast outside of the tye-block, (the starboard one, if two are used,) clinching the end aloft, above the eyes of the rigging, and sending the other through the lubber's-hole to the deck. Coil the lifts on the quarters of the yard, (stopping them to the jack-stays,) and reeve the braces with marrying-lines, observing to dip the starboard (or *upper*) one *over* the lower stay. Overhaul the top-burtons from aloft, and hook them to the yard-arms; as also a fore-and-aft tackle to the slings to keep the yard from chafing against the mast, as it goes up. Now man the hawser and starboard burton, and sway away, carrying the *port* (or lower) arm aft, and placing a mat under, to prevent injury to the deck. As soon as the yard is clear of the lower stay, ease the lizard, and commence crossing—keeping to the slack of the fore-and-aft tackle, and hauling on the lower burton and starboard brace. Reeve the lifts through the sister-blocks, and as the yard rises above the lower cap, square it; bring to, and pass the parrel, or *truss* the yard, as the case may be, sending down the fore-and-aft tackle. Now reeve the tyes (13) through the gins, (or mast-head sheeve;) splice in a single block to the reeving end, reeve the runner, and hook the fly-block with the halliards rove,* taking the strain from the burtons and hawser, which may be sent down,

* Vide Running-rigging.

together with the yard-block and lizard; observing, as a *finale*, to place a small square piece of wood between the slings and lower cap, to keep the yard from bowing, in case the halliards should be slacked, or let go.

N. B.—This routine supposes the yard to be lying in the *port* gangway, with the *starboard* yard-arm *forward*.

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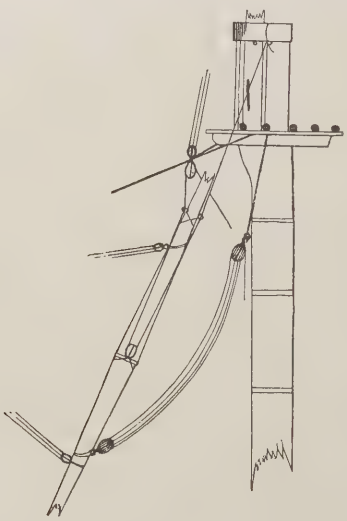
## LOWER YARDS.

In order to illustrate under one explanation all the principles involved in the operation of getting the yards on board, it will be necessary to grant the premise, assumed with regard to the position of the ship, viz.: at anchor in a *tideway*. Having lashed a stout block, with a hawser rove to the crotch of the lower-stay collar, (supported by a burton from the topmast-head,) tow the yard off to the ship, say on the starboard side, with the *port* yard-arm *aft*,* and secure a large single block to the slings, as also a bull's-eye on each side of the *port* quarter, well out on the yard. Through these reeve one end of the hawser, and clinch it over the lower cap, sending the other part through a leader on deck to the capstan.

Fig. 19.



Secure the bends and channels of the ship from chafe by proper means, and heave away, having the *starboard* pendant-tackle in readiness to hook to a strap on the starboard (or *forward*) yard-arm; as also two stout fore-and-aft jiggers to the quarters. When the *after* or port arm rises above the gunwale, and clear of the lower-rigging, cast the yard off from the ship forward, and as it is swept aft by the

* When there is no tide the reverse of this should be observed.

current, hook on the pendant-tackle and jiggers. With these sway it on board, and land it athwartships, on chocks, for that purpose, where it should be lashed to keep it steady; observing the precaution to place a shore under the slings, to prevent it from springing. After which, take off the blocks, bull's-eyes, burton, and tackles, and send the hawser down from aloft.

Now tar the yard-arms, and proceed to place the rigging on in the following routine:

1. Sling-band.—This is a modern substitution for the old D-thimble,* consisting of a stout iron band, going around the centre of the yard, with an eye-bolt on top, to which the slings are attached by means of a shackle. This falls within the province of the spar-maker, rather than the rigger.†

2. Quarter-blocks‡ are neatest if made of iron, with a stout broad sheeve, (of the same metal, when chain-sheets are used, or of *lignum-vitæ*, with rope or hide,) secured to the yard by a band, which is put on by the blacksmith. When fitted with rope, as is frequently the case in the navy, the blocks (which are large single ones§) are seized into *doubled* grommet-straps, (that are simply served, and a strip of leather put on the *after* part, as a preventive from chafe,) with a round lashing; after which, the straps are secured to the yard *on top* by a rose-seizing—the bights, or eyes, being hove close together with a heaver and Spanish windlass. The straps are then spanned towards each other with a lashing underneath, to keep the blocks from spreading.

3. Truss-straps and Pendants.—The adoption of the *patent iron truss* throughout the merchant service, and on board of all government vessels, below frigates, has done away with the necessity of the strap and pendant of "earlier times." But in large class ships-of-war, the "old fashion" (fitted as follows) still prevails. The *straps* (into which the truss-thimbles are seized) are formed of long and short grommets, made like those for the tye-blocks, and lash on each side of the slings with a rose-seizing *on top*, having the thimbles a little above the after centre of the yard. The *pendants* are best when made of four-stranded hide-rope, and leathered on the standing-part, which is made with an eye, and rove around the yard.‖ The other end (when rove) is fitted with a single block, the strap of which is formed by the bights of the strands.

4. Clew-garnet-blocks.—Although iron-bound, both in the navy and merchant service, they are sometimes fitted with rope-straps, which are single, with lashing-eyes, going around the yard, and secured on top by rose-seizings. They

* Vide Note for the manner of lashing it on.

† On board of vessels of war there are usually two additional bands—one on each side, for the *preventer* slings.

‡ In many ships, a small single or double block is secured to the centre of the yard (*prior* to putting on the quarter-blocks) by a rope-strap fitted with lashing-eyes, for the *slab-lines*.

§ In the merchant service they are more frequently *double* than single, in order to receive the reef-tackle, which is rove like that for the topsail-yard.

‖ One standing-part is placed *outside* of the thimble on the yard, and the other *inside*. This is done to avoid chafe, by crossing them, which otherwise would be inevitable. The cross-jack-yard, however, has but one truss, and consequently a single strap.

should, also, be wormed and served, and protected from chafe on the after-part by leather.

5. Straps and Thimbles, for standing-part of clew-garnet. These are single, and simply served, with lashing-eyes, which secure on top of the yard by a rose-seizing, *outside* of the clew-garnet-blocks.*

6. Rolling-tackle Straps.—Vide Ibid. Topsail-yards.

7. Straps and Thimbles, for studding-sail-boom, (somewhat more than halfway out,) fitted like that for the standing-part of clew-garnet. They are only used on the *fore* yard, except in a few ships, which carry a main-topmast studding-sail.

8. Burton-straps.—Vide Ibid. Topsail-yards.

9. Head-earing Straps.—Vide Ibid. Topsail-yards.

10. Jack-stays.—Iron ones are universal now throughout the merchant service; and by a recent regulation of the Navy Department the *bending* jack-stays of all government vessels are of iron also. But the late method of fitting the courses without after-points, renders *reefing* jack-stays necessary. These are invariably of rope, and fitted in the same manner as those described under the head of topsail-yards, with the exception, that in lieu of being secured by staples, *eye-bolts* are used,† which allows a space between the jack-stay and yard, for the passage of the points in reefing.

11. Foot-ropes.—Vide Ibid. Topsail-yards—the only exception being that the inner ends, in lieu of crossing abaft the mast, are connected to each other in the slings by a lashing *underneath* the yard, and this is seized up to the span of the topsail sheet-blocks. In the merchant service they are frequently secured to the arm of the patent truss.

12. Brace-blocks.—Vide Ibid. Topsail-yards.—Sometimes, in merchant ships, the brace-block is fitted with a long pendant, which connects to the shoulder-band, by means of a hook-thimble.

13. Lifts.—In all heavy ships the lifts are double, and reeve through single blocks, fitted with grommet-straps (which are wormed and served) going over the yard-arm outside, and last of all; the standing-part securing with a hook, to an eye-bolt in an iron crescent extending across the lower cap, while the other part is rove through a single block at the cap, and from thence to the deck, where a small jigger-block is spliced into the end, or attached by means of a hook and thimble. In the merchant service the lifts are single—connecting to the shoulder-band on the yard by means of a hook, and reeving through a block (or bull's-eye) secured to the lower cap.

Lastly. See that the carpenters and blacksmiths have attached all the necessary appendages to the yard, as cleats, boom-irons, &c., and send the chain-slings up by

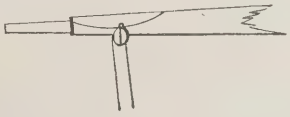
* Necessarily so, for otherwise the parts would *cross* and chafe each other.

† Observing, however, before reeving them, to place the upper eye of the stirrups over the bolt, by which a seizing is saved, and the jack-stay made to serve the purpose of a toggle.

one of the top-burtons, fitting them over the lower cap in a score usually cut for that purpose, and securing the two parts by a back-lashing abaft the mast-head. Pass a stout strap around each quarter of the yard, near the sling-band, and hook the lower blocks of the pendant-tackles to them—the upper ones being shifted to a heavy strap over and around the lower cap; hook, also, both top-burtons to the burton-straps on the yard, and reeve the braces. (Vide RUNNING-RIGGING.) Reeve and man the lifts, and sway aloft, keeping the yard clear of the lower-mast by the fore-and-aft tackles. Now when high enough, i. e. when the centre of the yard is a little above the futtock-staffs, key the truss, shackle the slings—unhook the pendant-tackles, burtons, &c., and square the yard by the lifts and braces.

This routine hardly answers for the cross-jack yard, there being necessarily many exceptions; among which, we may note the omission of jack-stays, clew-garnet, and slab-line blocks, as also rolling-tackle, head-earing, and burton-straps. It should be remarked, too, that the brace-straps, in lieu of going on after the foot-ropes, are secured by a rose-seizing *inside* of the shoulders, about one-sixth of the length of the yard-arm, having the breech of the block to rest against the forward side. This is done to obviate the tendency it has to slip off, arising from the sharp angle which the yard and brace form with each other, when close-hauled.

Fig. 20.



A better way, however, is to fit them with a span, going over the yard-arm, and seizing to a staple on top, as done on board of the frigate "Belle Poule" in 1845. The merit of this plan consists in affording all the advantages of a brace at the yard-arm, without the sacrifice of *leverage* incident to the usual method in bracing up.

NOTE.—When the old D-thimble is used, it is lashed on as follows: Parcel the centre of the yard in the wake of the thimble and lashing, having the parcelling wide enough to turn back on each side, and cover all. Place the thimble on the yard, with the score standing fore and aft; observing to parcel it well. Middle the lashing—usually a small strand of well-stretched rope, and pass the turns with both ends, from the centre out, heaving them well taut with a Spanish windlass, and racking each one in succession; taking the precaution that the turns do not ride each other on the yard. When all are passed, jamb the end between the lashing—haul over the parcelling, and sew it down neatly, covering the after-part with leather.

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## WHISKERS.

These consist of two gaffs—one on each side of the bowsprit, fitted with jaws, or hooks, like the dolphin-striker; and when compared with the complicated method of conveying support to the head-booms, by means of the old-fashioned spritsail-yard, are much simpler, and more frequently preferred; for reason of the little

trouble they occasion at sea, by rendering the operation of "canting" unnecessary. This plan has been almost universally adopted in the navy; although in the merchant service, and on board of the smaller class of war vessels, whiskers are seldom if ever met with, except in shape of a stout iron bar (at which the head-guys are secured to eye-bolts) diverging from the bow, at an angle with the cat-head*—a method obviously objectionable, on account of bringing nearly all the strain on the martingale, which is evident, whether we consider the vessel as careening under a pressure of canvas, or regard the jib as a *lifting* sail. The manner of fitting whiskers, however, varies in almost every ship, and depends as much upon the rigger's fancy, and ideas of security, as upon any special rule of seamanship. The following method, adopted on board of the frigate "Cumberland,"† was found to answer every condition; and is given here, for the guidance of those who may be at a loss which plan among the many to employ.

Sway the whiskers on board with a tackle on one of the forward swifters, and land them on the forecastle, with the small ends resting on the head-rail, at each side of the bowsprit. Rack the topmast-stays in the bees (in order not to disturb the position of the mast) before coming up, and reeve the ends through their respective holes in the jaws, taking the precaution to leather them on account of chafe. Then with the assistance of a jigger, from each fore-topmast stay, hooked to a strap around each whisker, (at the distance of about one-third from the outer end,) sway them out, until far enough to rig; and put over the *jib-guys*, which should be fitted with a cut splice, made to set exactly,‡ and so placed as to keep the whiskers perfectly square with each other. These splices are served, and covered with canvas. Now reeve the flying-jib-guys, (protected by leather at their points of contact,) through the holes bored in the whiskers for that purpose, and prepare to get them into their places—observing to have the bowsprit coppered in the wake of the ends—employing jiggers from the cap, hooked to straps around each jaw. With these rouse them forward, slacking the stay-jiggers, (which in this case, will serve the purpose of lifts, until they are secure,) and hauling on the jib-guys, in order to bring the whiskers athwartships. Lastly, pass the jaw-lashing, put over the *jumper-brace* and *standing-part of forward lower boom-guy*, then set up the ends of the topmast-stays and the jib, and flying-jib-guys, and take off the jiggers.

NOTE.—It is well to call the attention of the reader to the difference between the jumpers used at *sea* and *in port*—the latter being smaller. They are usually fitted with hook-thimbles in the lower ends, which connect to eye-bolts in the cut-water; and thimbles simply in the upper ones, lashing to the extremities of the whiskers.

* This latter plan coincides in part with the definition of whiskers given by Brady, who makes a distinction, and arranges the first method, under the head of "HALF SPRITSAIL-YARDS"—a classification, though quite independent of the "pent-up Utica" of nautical technology, possessing at least the merit of *originality* with "the author."

† They were substituted for a stationary spritsail-yard, across the knight-heads, after her arrival in the Mediterranean, and were formed out of a spare main-top-gallant-yard fitted with jaws, having holes bored in them to receive the stays and jaw-lashing.

‡ A good plan for fitting them is to form the eye by splicing a short piece of the same sized rope, into the guy: should it then be necessary to alter the eyes either forward or aft, on account of stretching, it would only be requisite to draw the ends, and resplice them at the proper place. This method was adopted on board of the "Cumberland," and by keeping the guys on a stretch for three or four days, previous to fitting them, they required altering but *once*, during a period of more than eighteen months.

*When preparing for sea,* slack the guys, (which must be set up again when the jumpers are secured,) and get the outer ends of the whiskers down to an angle of about 20° with the horizon. Then hook the (stout) jumpers to the cut-water, and set them well taut with a laniard, which is spliced into the thimbles of the upper ends.

It may not be altogether amiss here to add a "wrinkle" in *squaring* the whiskers in *port;* which may be done by simply clapping on the *guys,* and slacking the jumpers—*without* the necessity of a (troublesome) "*toppin'*-rope," through tail-blocks on the fore-stays, as *sometimes* practised by newly-fledged boatswains, when first "called" in the service.

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## TOP-GALLANT-YARDS.

Having brought the yard (fitted with an iron sling-band and jack-stay*) alongside, sway it on board with the long yard-rope, rove through the sheeve-hole in the top-gallant mast-head, by bending it on to the slings, and stopping it down to the forward yard-arm. Place it in the gangway on chocks—unbend the yard-rope, and prepare to place the rigging on, in the following order:

1. PARREL.—This is best when formed of single grommet-straps (a long and short one) going over the yard, on each side of slings, at a distance apart equal to the diameter of the top-gallant-mast, and cleated, to prevent slipping. These are made to fit snugly, by means of round seizings passed close to the yard on the after-part, leaving a surplus bight to each, which forms the lashing-eyes—that of the larger strap (marled together and leathered) being long enough to go around the mast, and meet the short one, (leathered also,) where it is secured by a lashing of small-sized ratling stuff, after the yard is crossed. In the merchant service, and on board of the store-ships, *jaws* are frequently put on the top-gallant and royal yards, in lieu of parrels, and have been found to answer every purpose; there being, however, a necessity for care in sending them up or down, lest the curve or shoulder of the jaw should be knocked off.

2. QUARTER-BLOCKS.—These are double, and invariably iron-strapped, connecting with a hook to a band on the yard. This is by far the best plan, as it saves a deal of trouble in sending the yard up or down. When rope is used, the blocks are single-strapped, with spliced eyes going around the quarters, and secured by rose-seizings on top.

3. STRAP AND THIMBLE, or *becket,* for the standing-part of clew-line. Vide Ibid. TOPSAIL-YARDS.

* In the "Cumberland," on the top-gallant and royal yards, the jack-stays spliced into the eyes of the foot-ropes, around which, on top, cringles were worked for the head-earings; a plan answering all the conditions of security, and in point of neatness, worthy of universal imitation.

4. Strap and Thimble for rolling-*rope*. (Vide Ibid. Topsail-yards.) This is omitted by many seamen, who deem it unnecessary, and send the yard down, when the sail is taken in. But it would be well to remember, that if it be kept aloft, and the rolling-ropes passed securely over the topmast cap, a considerable degree of support might be given to the top-gallant-mast, as the yard-arms thus act the part of out-riggers, and the lifts perform the service of shrouds. (Vide Part II. Evolutions.)

5. Strap and Thimble, for head-earing. Vide Ibid. Topsail-yards.

6. Foot-ropes. Vide Ibid. Topsail-yards. The inner ends, however, do not cross abaft the mast after the yard is sent up, but seize to the quarters.

7. Lift.—This is single with a round-eye (the splice of which is served) going over the yard-arm, (when swayed up for crossing,) and generally leathered to make it slip readily, off or on, as the case may be. In the naval service, it is cut of sufficient length to reach the top, after reeving through the bull's-eyes, between the top-gallant shrouds, and marled to the brace when the latter is single, in order to hold on, or come off together. But in merchant ships of the present day, the lifts are most always made to go *standing*, and secured to a becket, or thimble, under the eyes of the top-gallant rigging; a plan which is quite at "loggerheads" with square yards, and productive of "high-sounding" anathemas from the men in getting them over the yard-arm, particularly in a heavy swell, on the "threadbare" poles of a down-east merchant-man.

8. Braces.—When fitted double (which is nearly always the case in the merchant service) a single block is strapped into a grommet, which is wormed and leathered, and sets snugly over the yard-arm when swayed aloft. In this way it is not unfrequently marled to the eye of the lift.

Lastly. Splice the *snorters* (which are cut about half the length of the yard-arm, and simply whipped at the end) into the thimble of an eye-bolt at the yard-arm, hitching it to the rolling-rope strap; and prepare for crossing. The yard-rope, having a lizard attached, (overhauled down forward, and outside of all,) is rove through a good-sized grommet passed over the (upper) yard-arm, and hooked to the bolt in the sling-band; the lizard being rove through the rolling-rope thimble, and hitched to the one on the opposite quarter. Take the eye of the lower lift, and brace in the topmast rigging, and that of the upper one to the opposite side of the cross-trees, and sway aloft. When the upper yard-arm rises above the heel of the top-gallant-mast, take off the grommet—slip on the lifts and braces, gathering up the slack of the lower one, and sway away, until the slings of the yard are over the topmast cap; then take a turn with the parrel-lashing abaft the mast, through the eye in the opposite strap—tend the lifts and braces, jerk on the lizard, and sway across, squaring the yard, and passing the parrel for good and all.

## ROYAL YARDS.

The routine of rigging and crossing is precisely similar to that of the top-gallant-yards—the only difference being that the quarter-blocks are single, and straps for the rolling-rope and standing-part of clew-line are omitted.

NOTE.—In many ships small hand-grommets are worked around the jack-stays for the men to hold on by.

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## TRYSAIL-MASTS—GAFFS AND BOOMS.

These spars are usually swayed on board by means of the fore or main yard and stay-tackles—purchases most frequently in use, and convenient at this stage of the equipment.

### TRYSAIL-MASTS.

Of late an iron railway, on the after-part of the lower-mast, with sliding-bolts, to which the sail is bent, has been substituted for the trysail-mast of a less recent date, particularly in the vessels of the naval service,—a plan which possesses many advantages in point of looks, but attended with an infinite degree of trouble on account of the tendency in the bolts to slue and jamb, when hoisting or lowering the sail. In the merchant service, however, and on board of the store-ships, this method is not adopted; the gaff being frequently stationary with hanks on it, for the sail, which is bent to an iron jack-stay, secured by staples, or to a wooden batten on the lower-mast, and set, or taken in with *in-and-out haulers;* although a preference exists in many instances for the old trysail-mast, which is shipped by means of a tackle hooked to a strap above the futtock-band; the head being pointed through a hole in the after-chock, and the heel (over which the hanks are passed) stepped in a socket, or mortice, on the fife-rail, or a shoulder, bolted to the lower-mast just above the deck; after which, the head is secured by a lashing through a B-cleet underneath the top, or with iron keys; copper having been put on, in the wake of the gaff.

NOTE.—In merchant vessels, the *fore*-trysail is sometimes dispensed with, and its absence supplied by the main-staysail; but it is nevertheless worthy of remark, that the Americans are almost the only ones who equip their ships with a trysail, forward; an exception being sometimes met with among the Danes and Russians. This "mark of distinction," or the absence of it, is often serviceable in *guessing* a vessel's nationality.

### GAFFS.

These are fitted in a variety of ways,—having jaws, with a trysail-mast; stationary, and secured to the lower-mast by means of eye-bolts within each other, (like lock-thimbles,) when a batten or jack-stay is used; or with a sliding-chock, when

fitted "railway fashion." The introduction of iron has done away with much of the gear incident to gaffs in former times; and the *vangs* and halliards are about all now that fall within the province of the rigger—the brail-blocks being superseded by sheeves (for that purpose) in cheeks fitted by the carpenters at each side of the gaff; while the blocks for the throat and peak halliards are iron-strapped, and connected to bands with eye-bolts.* The vangs are best when fitted with a cuckold's-neck, which is wormed and covered with canvas, having a neat seizing at each side, and cleated both forward and aft, to prevent slipping. The gaff is sent up by the halliards, and the jaw-lashing passed, or the eye-bolts riveted, as the case may be.

NOTE.—The *spanker*-gaff should always be fitted with throat and peak halliards to hoist and lower, as necessary; for otherwise it would be almost impossible to reef the sail, which by-the-by is frequently the case in the merchant service. In brigantines and schooners, it is not unfrequently the case that eye-bolts are attached to each side of the jaws, for preventer lashings in heavy weather; and a single block (grommet-strapped) is put over the gaff-end for a down-haul; vangs being dispensed with as useless, on account of the sharp angle at which they act, in consequence of the height of the gaff.

## BOOMS.

That for the *spanker* is neatest, if shipped with a goose-neck to an eye-bolt on the mizen-mast, and fitted with an iron band over the boom-end for the topping-lift, (when single,) and the guys, both of which connect to it with sister-hooks. The *sheet-blocks* are best if strapped with rope-grommets, on account of the jerks and checks of gibing, which render eye-bolts liable to snap and break at the neck. The *foot-ropes* are formed with round-eyes (wormed and served) going over the boom-end, and seizing to staples inside of the taffrail. The topping-lifts (one on each side) are usually fitted with sister-hooks in the ends to an iron span, about one-fifth of the extreme length of the boom from the outer end; while the running-parts reeve through blocks at each side of the mizen lower tressle-trees, and thence to the deck, where gun-tackle purchases are attached. In men-of-war, particularly those of the smaller class, and in the merchant service, the topping-lift is not unfrequently single, and rove through the gaff-end, and a roller in the after-part of the mizen lower-cap, having a jigger connected to it, by means of a hook and thimble. The *sheets and guys* are best if rove in *one*, which may be done, by either having the standing-part over the boom-end, or attached to the blocks at the quarters. (Vide Ibid. RUNNING-RIGGING.) The *out-haul* (going around the boom with an eye, is rove through a block on the clew of the sail, and a sheeve in the boom) should be of *hide*-rope, which is far better calculated than hemp to stand the wear and tear, and friction of constant use. On the *main-boom* of brigantines and schooners, the topping-lift is usually fitted with the standing-part secured at the mainmast-head by a hook in an eye-bolt of the wythe; while the lower end is spliced around a double block, in which a fall is rove, leading through a single one, and a sheeve in the boom. In this class of vessels, no out-haul is used; the clew of the sail shackling to a band

* In the "Fairfield," where the trysails were fitted with a railway, the gaffs were stationary, and supported by a single leg, (from a bolt in the after-chock,) spliced around a thimble on a span attached to the gaff,—a method which, though neat, was nevertheless troublesome in bending the sail.

around the boom, inside of which an iron traveller, covered with leather, is shipped for the purpose of securing the reef-cringles in reducing sail, each successive reef bringing the traveller nearer to the mast. A heavy strap, (which is cleated forward,) with thimbles at each side, is put around the boom about halfway out from the jaws, for the boom-tackle pendant, which is fitted with a hook and thimble in each end, and used only in going large. The *crotch-ropes* (an essential requisite in the management of a boom-mainsail) are usually served all the way, and fitted with a hook in one end for a stout eye-bolt in the quarters—the boom being protected by copper in the wake of them, just forward of the sheet-blocks, which should be double-strapped with rope. These, with the addition of belaying-cleats for the topping-lift and reef-pendant, (fitted of hide-rope, and reeving through a sheeve in the boom, with a jigger attached,) complete the equipments. The boom is then got in its place by means of the *throat* halliards and topping-lift, assisted by guys and athwartship tackles, as requisite.

## STUDDING-SAIL BOOMS.

That for the *lower* studding-sail is fitted with an iron goose-neck and key, which connects to a bolt in the forward part of the fore channels; and is shipped either by means of the fore and main yard-tackles, or with burtons on the standing-backstay and forward swifter of the fore-rigging. On the outer end, about two-thirds from the goose-neck, an iron band is put over the boom, having eye-bolts on the forward, upper, and after sides, for the topping-lift, and the guy-blocks;* and in vessels of war, *mooring* pendants with large thimbles in the lower ends for the boats, and a Jacob's ladder, are attached, by lashings like those used in securing the foot-ropes on the topsail-yard. These, with the *topping-lift*, (which is fitted with sister-hooks, connecting to the boom, and reeving through a small clump-block, seized between the forward (lower) swifters, above the futtock-staff, with a double or single purchase in the end for the fall,) and the *out-haul block*, double-strapped with rope, having an eye to set taut over the boom-end, constitute all the *standing* gear, falling within the province of the rigger, except perhaps the *lizard*, the thimble of which traverses on the topping-lift, and is used as a fair-leader at the outer quarter of the fore-yard in getting the boom out or in.

Note.—When the boom is not in use, it is hauled alongside by the after-guy, and rests in cranes, shipped for the purpose in the waist—the topping-lift being stopped down the forward swifter. Not unfrequently in English vessels, particularly men-of-war of a large class, the topping-lift is rove through a stationary bull's-eye on the fore-yard, and a span-block at the lower cap—a plan which dispenses with the lizard, but less economical than the method given above, on account of requiring more rope.

The frequency of accident to *topmast studding-sail booms*, at sea, often renders "shifting" a necessary operation, and this consideration is deemed sufficient, by many men of experience, to recommend the fitting of both extremities alike, viz. tapering with a score and hole for the heel-lashing—that in the outer end (while in use as such) being "plugged" with wood, which can be readily driven out in case

* In the merchant service, the guys are most frequently single, and are fitted simply with sister-hooks.

of a necessity for a "shift."* Through the hole in the inner extremity, reeve the *heel-rope*—turn a Walker's knot in one end, and whip the other—unclamp the irons on the yard, and prepare for sending the boom aloft. Hook one of the top-burtons to the lower lift, somewhat more than halfway down, and send the fall to the deck "before all," attaching the lower block to a bight formed by hitching the heel-rope over the boom, and stop the standing-part down towards the outer end. Bend a hauling-line, from the slings of the yard, on to the heel, and sway aloft, pulling up steadily on both, until high enough. Then pass slip-ropes over it—point it fair through the pacific-iron, and rouse on the burton, cutting the stops as requisite, until sufficiently far to place the *lower studding-sail halliard-block*, and that for the *tack*, over, fitted with straps setting tautly around the boom-end, and kept from slipping off by an iron pin passed outside of both. After which, clamp the boom-irons; pass the heel-lashing, (through its thimble on the jack-stay;) rig out to the square mark, and take off the burton, tripping-line, and slip-ropes. Lastly, seize a hook horizontally on the yard at the "rig-out mark," with the point out-board, for the purpose of securing the boom, when setting the sail,† and fit the in-and-out jigger, ready for use.

Note.—In many merchant vessels these booms are fitted to traverse *under* the yard. But the plan is objected to, by "many men of many minds," on account of the chafe induced by a constant contact with the topsail sheets, the unhandiness of securing the heel, and the clumsy appearance given to the yards in port—the sole advantage being, that the boom is out of the way in reefing or furling sails.

The *top-gallant studding-sail booms* are rigged nearly in the same manner, with the exception of a halliard-block at the outer end, and a score in the heel; and in lieu of being retained on the yard by boom-irons, it is usually (and best) made to traverse on a rope jack-stay, which is seized to the eye of the topsail-lift, and sets up to its opposite in the slings of the yard. The *tricing-line*, (leading through a small block hooked to a thimble seized between the forward-swifters, close up to the eyes of the topmast rigging,) when required to rig the boom out, is made to answer the purpose of an in-and-out jigger, thus: The block is hooked to a stationary thimble well out on the yard, and from thence the tricing-line leads into the top. The boom (fitted with a becket in the heel) then toggles to a travelling thimble on the jack-stay; and when required for setting the sail, is secured by means of a lashing passed over a hook on the yard, like that for the topmast studding-sail boom, already mentioned. In the merchant service, this "extravagance" is not common, although it has many advantages to recommend it; but one must bear in mind that "*owners*" and "*captains*" are not *always* synonymous terms.

Note.—The booms on the topsail-yard are usually sent up by the halliards, rove through the jewel-block, which is secured to the forward-swifter of the topmast-rigging, and the boom slung in a span. For the manner of reeving the gear, vide Running-rigging.

* Should this plan of fitting the boom not be preferred, and it becomes necessary to shift it to the opposite yard-arm, for use, it may be done as follows: Unclamp the boom-irons, and rig in, until clear of the "pacific," taking off the blocks at the end, and changing them to the other side, ready for placing over when the boom is transferred. Trice the heel up to the lower-stay collar, (securing it there with the lashing,) and lower the outer end down by means of the topmast studding-sail halliards, rousing it up on the opposite yard by the other halliards, overhauled down outside of all for that purpose. Then slack the heel-lashing, rig out, put over the blocks, clamp the irons, &c.

† The heel-lashing is passed over the hook, and back through the score in the boom, and two half-hitches taken with the end around all parts.

## RUNNING-RIGGING.

In the fitting of running gear there are two essential observances—economy, and an assimilation in size between the ropes and blocks, both of which may be attained by following the rule laid down by Glascock, who says it "is not recommended to *cut* and reeve, but, on the contrary, to *reeve* and cut"*—a principle which is founded on the "fundamental formula" of *all* professions—viz. *common sense*. Having stretched the rigging, (by "thorough footing" it, i. e. passing the end through the coil, and then taking it to the capstan,) commence reeving it in the order of its importance, in which we may "reckon," as first,

### BRACES.

Fore-braces.—In the navy, the standing-parts are rove through holes in the fore part of the main-bibbs, (having overhand knots in the ends;) through the blocks on the yard, (from *in, out,*) thence back through others on the outside of the bibbs, and down to the sheeves in the fife-rail, (usually) from *aft, forward*. In merchant vessels, the standing-parts of the fore-braces are most frequently made fast to the strap of a single block in each of the yard-pendants,† and thence rove to double ones on the bulwarks just forward of the gangways, having the hauling parts in the second sheeves of the latter. This plan requires less length, and yields a better purchase than the method practised in the navy. But an occasional unkindly "clip" from the clew of the mainsail in tacking, and a constant exposure to dampness and wet, often illustrate the fallacy of this *economical* rule.

Main-braces.—The standing-parts are clinched, or fitted with running-eyes, over the bumpkins aft—then rove through the yard-blocks from *out, in,* back to others, (*inside* of the standing-parts,) and through sheeves in the bulwarks. In the merchant service the main braces are rove like the fore.

Cross-jack Braces.—The standing-parts are spliced into the strap of a *double* block‡ hooked to an eye-bolt on each side of the mainmast, in a line with the yard§

* If the absence of quotation marks, and the omission of italics, be any criterion of *originality*, it is certain that "the author" of the *Kedge Anchor* must have been afflicted with some pretty strong *symptoms* of this very same excellent idea, when *he* "recommended, *not* to cut and reeve, but, on the contrary, to reeve and cut;" particularly, if we analyze, somewhat *critically*, the expression of it. For example: "the contrary" of "*not* to cut and reeve," is evidently "*to* cut and reeve;" the coincidence with Glascock being "passing strange," except perhaps, that he wrote with "a pen," and Brady "with the marlinspike," with which he acknowledges himself so well "versed;" a circumstance which may account for the *negative* getting *astern* of the *past participle*. (Vide Preface, and page 249 of the latter's "work.")

† Vide Brace-blocks, Lower-yards.

‡ The outer sheeve of which then answers for the mizen top-bowline.

§ The reason is obvious: for if it were otherwise, the angular action of the brace would cant the yard either up or down, and consequently slack one or the other of the mizen-topsail leeches.

—thence to the yard-blocks from *out, in,* and back to the inner sheeves of those on the mainmast.

Fore-topsail Braces.—The standing-parts are hitched above the eyes of the main-topmast rigging, and seized to the collar of the stay, (to avoid chafe from the foot of the top-gallant-sail;) thence forward, and *down* through the yard-blocks to others on the main-stay, and at the bibbs. In merchant ships, the yard-blocks are generally attached to pendants, and the braces, in lieu of leading to the main-stays, are brought to the bulwarks like those for the lower yards.

Main-topsail Braces.—The standing-parts are hitched to the mizen-topmast-head, and seized to the stay-collar; thence rove to the yard, and down to span-blocks on the mizenmast, about halfway between the top and deck. In many ships the standing-parts are secured to a strap which travels up and down the mizen-topmast with the parrel, (in order to shift the strain lower down, as it becomes greater, and sail is reduced,) a plan frequently met with in the merchant service, and possessing many commendable features.

Mizen-topsail Braces.—The standing-parts are secured to the strap of a block at each side of the main lower cap; thence to the yard, and back to the blocks, and so down through the lubber's-hole to the deck.

Fore-top-gallant Braces.—In the navy they are usually rove single, the standing-parts going over the yard-arms with the lifts—thence through leading blocks on the main topmast-stay collar, and others, under the eyes of the topmast rigging—whips (the standing-parts of which are secured to the lower tressle-trees) being attached to the ends. In merchant-men the top-gallant braces are invariably rove double, through blocks going over the yard-arms, and the standing-parts seizing to the topmast-stay collar; this plan renders whips unnecessary, the purchase being deemed sufficient without them.

Main-top-gallant Braces.—Vide preceding, and substitute *mizen* for "main."

Mizen-top-gallant Braces.—In reeving these braces, which are almost always single, there appears to be but one method, viz. through the inner sheeves of small double blocks, underneath the main-topmast cross-trees—the outer sheeves being used for the bowlines.

Fore-royal Braces.—These are single, (without whips,) and rove like the top-gallant braces, except that they are taken to the main-top-gallant mast-head and stay, in lieu of lower down.

Main-royal Braces.—Same as fore-royal braces, except taken to the *mizen*-top-gallant mast-head, and through blocks on the stays.

Mizen-royal Braces.—Single, over the yard-arms, and through middle sheeves in the after-chock of the main-topmast cross-trees, the outer ones being used for the royal bowlines.

Topmast Studding-sail-boom Braces.—These (which are confined chiefly to vessels of war) may be either single, going over the boom-end with a running-eye, and leading through a tail-block on the forward-swifter of the main rigging; or double, with a pendant and whip leading to the main-rigging also.

Preventer Braces.—These are fitted variously, but the best and most economical way, is with a *pendant* and *whip*, the former going round the yard, hooking to its own part, and the latter led to the deck, well aft.

## HALLIARDS.

Topsail Halliards.—Where double-tyes and gins are used, the standing-part of the halliards is made fast to a single block, (which is iron-strapped and fitted with a swivel,) in each side of the channels, and then rove in a double one connected to a thimble in the end of its respective tye, by sister-hooks. In the merchant service, and on board of the smaller class of war vessels, where gins are dispensed with, and a single-tye is employed, a runner is rove through a single block spliced into the end of the latter, and the double one of the halliard purchase* hooked to an extremity of the runner, which is fitted with a thimble; the other (or standing-part) making fast to a bolt in the after-chock. When the halliards are used, the hoisting part is rove through a leader on deck.

Top-gallant Halliards.—On board of large class ships of war, it is usual to fit the top-gallant-yard with a "regular" tye and runner. But this plan is manifestly too expensive and troublesome to meet with much encouragement in the merchant service—a yard-rope being also requisite, in case of sending the yard up or down. Indeed, the best and most economical method is to have a double-and-single tackle hooked to a bolt in the lower tressle-tree, and fitted with two lizard-tails, which connect to the yard-rope, just below the eyes of the topmast rigging, the hauling part of the purchase being sent through the lubber's-hole to the deck, and the surplus end of the yard-rope coiled, or flemished down snugly in the top.

Royal Halliards.—These are best, if fitted with a simple whip, which is formed thus: The yard-rope being rove in a leader on deck, is passed through a single block, (fitted with a strap having an eye,) and toggled on at some distance above the bulwarks, as represented in the annexed figure. In the event, then, of having to send the yard down, it is only necessary to take off the block, which will leave the yard-rope clear for running.

Fig. 21.

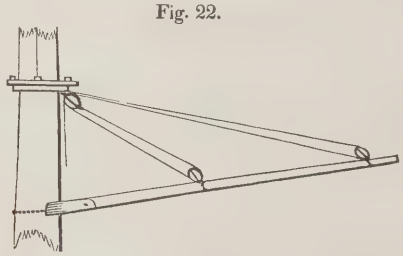
Throat Halliards.—If for a spanker, or trysail, they usually consist of a purchase rove through double and single blocks; the former hooked to a bolt on the under side of the after lower-chock, and the latter to a band and eye-bolt on the inner end of the gaff; the hauling part leading through

* This block is usually connected by means of spider-legs to a *clamp-ring* (which is parcelled and leathered) around, and travelling on the standing-backstay, in order to keep the turns out of the halliards when let go, and the block from chafe by contact with the top, (and the *hard* heads of "curious people" lounging over the rail.)

the upper block from *aft, forward,* to the deck. In brigantines, and vessels with a boom-mainsail, both blocks are double.

Peak Halliards.—The best plan for peak halliards is to reeve them as follows: Splice the standing-part into the breech of the mast-head block, (which is double,) and reeve from thence, through the *inner* block on the gaff, from *aft, forward;* then up through the *port* sheeve of the mast-head block—out through the block at the gaff-end, from *forward, aft;* and lastly, back to the starboard sheeve of the mast-head block, as illustrated in the accompanying cut.

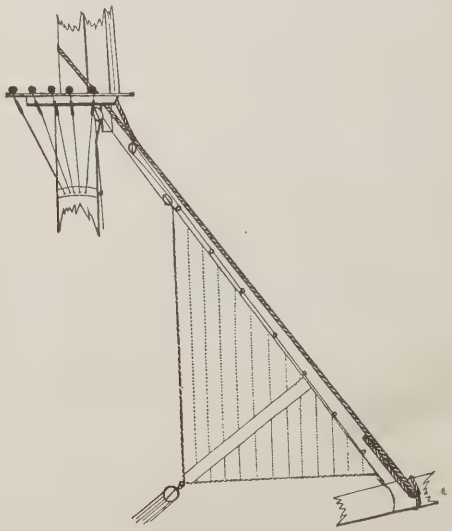
Fig. 22.



The merit of this system will be apparent, if we consider that the hauling part, by being rove *last,* at the gaff-end, permits the peak to drop the instant the halliards are let go.

Storm-staysail Halliards.—The following simple method of fitting the stay and halliards *in one,* is recommended, as obviating in a great measure the expenditure

Fig. 23.



of rope for "staysail gear," so universal both in the navy and merchant service. The *stay,* which is somewhat longer than the luff of the sail, and of the necessary size, is rove through a stout thimble seized into a strap around the bowsprit, (or lower-mast, as the case may be,) and turned in cutter-stay fashion, or connected by means of a hook. The *halliards* being rove from a leader under the top, to a block

on the head of the sail, and another at the crotch of the lower-stay collar, (as in the preceding figure,) are then spliced into the upper end of the stay, which is passed through the hanks. The advantages of this plan consist in tautening the stay as the sail is hoisted, and in dispensing with a downhaul, which is rendered unnecessary, by letting go the halliards, and hauling aft on the sheet.

Jib and Topmast-staysail Halliards.—The best manner of leading these ropes, is a matter of opinion, formed, in a great measure, from whatever may be uppermost in the mind of the rigger; as fancy, security, neatness, or desire for "professional greatness" in the shape of a new invention—contingencies often productive of some *grand faux pas* in subsequent practice.* In the store-ship "Southampton," while attached to the African squadron, the jib and staysail halliards were rove in the lower sheeves of iron fiddle-blocks, hooked to a bolt in each side of the topmast tressle-trees—the former double, through a block on the head of the sail, with the standing-part lashed to the crotch of the stay-collar; and the latter single, with sister-hooks to the head-cringle, and a whip, the block of which came just below the eyes of the rigging, when the sail was taken in. In point of neatness and security, this plan was found to correspond with all the essential conditions of good seamanship; for, in shifting topmasts, or in performing any other necessary evolution, "touching" these ropes, the blocks only required to be unhooked, while the upper sheeves served for the topsail buntlines.

Note.—The jib-halliards should be led on the *starboard* side, and those for the staysail vice versa—a rule which is self-evident, when we remember that the latter is set on the *port* topmast-stay. The method of fitting these halliards with *whips*, is not approved of by seamen generally, on account of the liability to tangle and get foul in hauling down the sail; and the obvious necessity of separating the parts widely from each other. And again, where the steeve of the bowsprit is not very great, and the mast is made to rake *aft*, not unfrequently a *certain* mathematical truth about the *hypotenuse* being the *greatest side* of the *triangle*, is comprehended, for the first time, after the aforesaid "whip" has been *cut* from the coil.

Flying-jib Halliards.—These are invariably rove single, through a neat block secured at the hounds of the top-gallant-mast, (on the *port* side,†) under the eyes of the rigging, and connected to the head-cringle on the sail by means of sister-hooks. In large ships, however, they are sometimes rove double, and the standing-part seized to the splice of the stay on the *under* side.

Gaff-topsail Halliards.—These are single, and in barks and ships are rove through a sheeve in the top-gallant mast-head, and attached to the yard with a *fisherman's bend;* or if the sail is triangular in shape, to a becket in the head-cringle, with a *sheet-bend*. On board of schooners and hermaphrodite brigs, they are rove through a sheeve in the *topmast*-head.

* For example: Fordyce recommends "a very *neat* and handy mode of fitting the jib-stay and halliards," which consists of "a spider-hoop, screwed on to the mast-*head, just under* the topmast *cap*," &c. This "good plan" might have done very well before top-gallant-sails came into fashion; but it is pretty certain now, that the *foot* of the sail, and this "stuck-up" stay, would "*wail* and gnash" each other amazingly.

† A block precisely similar to this one is lashed on the starboard side for the top-gallant buntline

Lower Studding-sail Halliards.—In the navy the *outer* ones are rove through a block hooked into the thimble of the burton-pendant; thence to the halliard-block at the end of the topmast studding-sail-boom, and attached to the yard with a fisherman's bend. In merchant vessels, where the burton-pendants are dispensed with, they are rove through a span-block on each side, which is secured with lashing-eyes *above* the topmast rigging, and forward of the shrouds—the hoisting-part being on deck through the cross-trees and the lubber's-hole. The *inner* halliards are usually formed out of the fore clew-jigger, hooked to the inner head-cringle of the sail, and a strap around the cap-shore, clear of the top rim.

Topmast Studding-sail Halliards.—These are rove on each side through a single block—the span of which is passed over (and seized together under) the topmast cap, between the doublings of the mast, being sufficiently long to reach forward of the top-gallant shrouds; thence *abaft** the topsail-yard, through the jewel-block, and so to the deck, where they are attached to the central part of the studding-sail-yard with a fisherman's bend.

Top-gallant Studding-sail Halliards.—These are rove on each side, through a single block, (which is fitted with a rope-strap and tail,) hitched above the eyes of the top-gallant rigging; thence *abaft*, to the jewel-block, and so to the top, where they are bent to the studding-sail-yard, in the same manner as the halliards previously mentioned—the hoisting-part being sent down *between* the horns of the cross-trees, to the deck abaft, and clear of all.

## SHEETS.

Fore and Main Sheets.—The standing-parts are connected to eye-bolts on the outside of the bulwarks with sister-hooks, just *forward*† of the sheeves for the hauling-parts; from thence, they are rove *up* through the blocks at the clews‡ of the sail, and back, in-board, through the bulwark sheeves. In the merchant service,

* Seamen are still at issue on this point, and Brady says "the halliards should be rove on the *fore* side of the topsail-yard"—an opinion coincident with that of many others, who argue that the sail, by bellying forward, slues the jewel-block, which brings the halliards (if rove *abaft*) in contact with the shoulder of the yard. This is true to a certain extent, and so long as the yard remains *square*, (which is far from being the case *always* with studding-sails set;) but when the parallelism subsisting between it and the halliards is destroyed by *bracing forward*, the contact, and consequently the only *possible* cause of chafe, is removed. If, on the contrary, the halliards are rove forward of the yard, it is evident that they would not only chafe against the clew of the top-gallant-sail, but over the boom on the topsail-yard, and with an intensity and force proportioned to the angle formed by bracing.

† The difference between three feet *forward* of the sheeve-hole, and three feet *abaft* it, is equal to a fathom of rope.

‡ These are best, if secured to the cringle by means of a *shackle*, which should be made large enough to receive the tack, and clew-garnet-blocks also. This plan was adopted in 1845, on board of the "Cumberland"—a ship, at that time, distinguished for neatness and efficiency; and it cannot be too strongly recommended, on account of the facility it affords in shifting courses, by a riddance of the clew-blocks, which, as permanent fixtures, render the reeving of tacks, sheets, and clew-garnets, an essential and troublesome feature—to say nothing of the increased weight and room of the spare sail, or the expenditure of blocks

where the tacks and sheets are often single, the clew-blocks are dispensed with, and the standing-parts are shackled, or simply clinched to the cringles.

Topsail Sheets.—When double, as on board of large class ships-of-war, the standing-parts are fitted with running-eyes, which go around the yard-arms *outside* of all, and thence rove from *out, in,* through the clew-blocks to the yard-sheeves, and the quarter-blocks in the slings; being led, lastly, to the bitts on deck, forward of the mast. If single, (in which case the *reeving* parts should be of *hide*-rope,) they are simply secured to the clew-cringle with *inside* clinches; but where chain is used, as in the merchant service, they are connected by small stout iron shackles. On board of *polaccas,* (a class of vessels peculiar to the Mediterranean,) topsail-sheets are not used, and the clews of the sails are lashed to large beckets on the lower yards, fitted for that purpose.

Top-gallant and Royal Sheets.—These are always single, and attached to the clews of their respective sails by sister-hooks. The former are rove through the topsail-yard, to the *after*-sheeves* of the quarter-blocks, (in the wake of which they were best, if formed of hide-rope;) from thence they are led through the lubber's-hole to the deck. The latter are rove in the same way, except through the sheeves and quarter-blocks of the top-gallant-yards, and thence through thimbles on the futtock-staffs of the topmast-rigging (abreast of the *second* shrouds) to the top, or deck, as may be preferred.

Storm-staysail Sheets.—These are temporary purchases, and consist usually of stout deck, or pendant-tackles, hooked (and moused) to the clew-cringles, and brought well aft, in order to form, as near as possible, a line with the foot of the sail. The hauling-part should then lead from the *forward* block, by which a greater purchase is obtained; although the reverse of this is advocated by many seamen, on account of the difficulty sometimes experienced in getting a turn with the belaying-end, in consequence of the flapping of the sail; but this objection will be entirely overcome, if the sheet be hauled aft, and the foot taut, before hoisting.

Trysail Sheets.—The best plan for fitting these is to have a long pendant attached to the clew of the sail for the fall to hook into, as it saves the trouble of "lighting up" the blocks to hook and unhook in shifting the sheet, as in wearing ship, &c.

Jib and Topmast-staysail Sheets.—Both of these are generally fitted with a whip and pendant, as follows: The latter, which should be in length equal to about one-third of the foot of its respective sail, is wormed and served; and after being middled, a good-sized thimble (around which the parts of the pendant are crossed) is turned in with a throat-seizing. It is then secured to the clew-cringle of the sail (in bending) with a stout lashing, and the standing-parts of the sheets, after being hooked, or clinched, to an eye-bolt in each side of the bulwarks,† are rove from *out,*

* In merchant vessels, where the quarter-blocks are *threefold,* the top-gallant-sheet is rove in the *middle* sheeve.

† The position of the bolts and blocks (or sheeves) must be such, that the sheet, when taut, shall form a line at right angles with the luff of the sail—for otherwise, either the foot, or the leech,

*in*, through a single block spliced into each end of the pendant—the hauling-parts leading in-board on the forecastle to belaying-cleats.

Note.—Both parts of the topmast-staysail sheets are secured *inside* of those for the jib.

Flying-jib Sheets.—These are single, and usually consist of one piece of rope, which is middled and fitted with a thimble, (like the pendants mentioned in the preceding paragraph,) and secured to the clew of the sail in the same manner. The parts are then led each side of the boom, in-board, through a thimble on the whiskers, (where whiskers are used,) and a fair-leader in the head rail, to the forecastle.

Spanker Sheets.—These are invariably rove in *one* with the guy by either of the following methods, viz.: The standing-parts are put over the outer extremity of the boom with a cut-splice eye, or connected separately with sister-hooks, and rove to the (double) block in each quarter; thence through the sheet-blocks from *forward*, *aft*, and back to the second sheeves of the quarter-blocks. *Or*, the standing-parts, after being spliced around (and forming the straps of) the quarter-blocks, (which in this case should be single,) are rove from *aft*, *forward*, through the sheet-blocks; thence from *forward*, *aft*, through those in each quarter, to the guy-blocks, at the outer end of the boom, and then in-board again, to the second sheeves of the sheet-blocks.

Boom-mainsail Sheets.—In small craft, as schooners, &c., a single purchase of double-blocks, and working on a traveller, is used; but in larger vessels, two (attached by separate straps, and hooked to eye-bolts in each quarter) are employed to manage the boom—the hauling-parts in either case leading from the upper block. This latter method is by far the best, as every one who has had to "gibe" a boom-mainsail, with a single sheet and crotch-ropes in heavy weather, will bear witness to.

Gaff-topsail Sheets.—These are formed of a single piece of rope, which is middled, and the bight passed through the clew-cringle of the sail; the ends being thrust also through the bight, are led down on each side of the gaff to a belaying-cleat on the boom near the jaws.

Studding-sail Sheets.—Those for the *lower* studding-sail consist of a single piece of rope, passed through the inner clew-cringle like those for the gaff-topsail; and in setting the sail, one sheet is rove from *forward*, *aft*, through a thimble or block on the goose-neck, in order to bring the clew close down to the boom, and the other led in-board on the forecastle to tauten the foot of the sail.

In fitting a *topmast* studding-sail, two sheets are also required, which are attached to the clew in the same manner as those for the lower studding-sail. One (called the *short sheet*) being passed *forward* of the topsail, and *aft* through a thimble (seized to the jack-stay on the outer quarter of the lower yard) into the top, where

would become slack, and the jib thus be deprived of a great portion of its efficacy. Indeed, this consideration is too often overlooked in the equipment, much to the detriment of the sailmaker's reputation, and the "standing" of the jib.

it is belayed to a cleat; and the other, or *deck-sheet*, being led to the forecastle, *forward* of the yard.

Note.—In merchantmen, only a single sheet for the topmast studding-sail is used, leading to the opposite side of the forecastle—the sail being cut with a slope on the foot, which brings the clew below the lower yard.

The *top-gallant* studding-sail sheet is simply spliced into the clew of the sail, (having parcelling on it for two or three feet below, to avoid chafe from the foot-rope of the topsail-yard,) and led into the top, where it is hitched around the forward-swifter. In merchantmen, where the sail is more frequently set from the *deck*, the sheet is led there also.

## TACKS.

Fore and Main Tacks.—These are invariably rove double, (except now and then in the merchant service, on board of small vessels, where they are single,) and fitted with the inner end tapering. The standing-part, which is wormed and served for a fathom or so from the end, (as a protection from wet,) is clinched, or passed over the extremity of the bumpkin* with a running-eye, and rove up through the tack-block at the clew of the sail—then back through a leading-block inside of the standing-part, and a hole in the bulwarks.

Note.—*Glascock* recommends (although not in very *intelligible* terms) a simple method of fitting the tacks for "singling" or "doubling" at pleasure, which consists in thrusting a toggle of *lignum-vitæ*, into the standing-part, about two fathoms from the extremity. A piece of small-sized rope, of sufficient length, is then spliced into the reeving-end, to serve the purpose of a hauling-line, and when it is required to single the tack, for hauling up the sail, it is only necessary to cast off both parts. Again, in setting the sail, the 'hauling-part is run on board, the toggle taking the block, until a certain strain is brought upon the rope, when the standing-part of the tack, which is hanging downwards, is immediately secured to the bumpkin, and the shell of the block relieved from the strain which the toggle would otherwise produce.'

'If it be required to set the sail, with a *double* tack, haul down on the small leading-line attached to the standing-part, and take a turn or two with it around the bumpkin. By this movement, the tack is doubled in a few seconds.'

Studding-sail Tacks.—These are either bent to the cringles of their respective sails with two half-hitches, or an inside-clinch, and rove from *in, out*, through the blocks at the boom-ends. That for the *topmast* studding-sail being led aft, through a tail-block on the forward-swifter of the main-rigging; and the tack of the *top-gallant* studding-sail, through a leader strapped around the lower dead-eye of the after topmast shroud; although in the merchant service it is oftener brought directly to the deck, and belayed well aft.

Spanker and Boom-mainsail Tack (lashings) are passed through the cringle, (into which they are spliced,) and an eye-bolt on the upper side of the boom.

* The *main* tack is secured to a bolt and block in each of the water-ways, forward of the gangway, being rove like the fore, to the block on the clew of the sail.

NOTE.—In laying to, in a small vessel, under a balanced-reefed (boom)-mainsail, the tack of the sail should be lashed up to the jaws of the gaff, and the whole hoisted several feet up the mast by means of the throat halliards. In this way the sail is elevated to the wind above the waves, and in the event of being boarded by a quarter sea, it cannot lodge in the belly of the sail, but will pass between it and the boom.

JIB AND STAYSAIL TACK (LASHINGS.)—These consist of a single piece of rope, spliced into the tack-cringle of the sail, and lashing it to the *stay*, around which it is passed, and the end hitched. This plan is preferable to that of lashing the tack to a hook or bolt *on* the *boom*, as recommended by Brady and others, particularly if we regard the jibs as *lifting* sails, and the head-booms as mere *outriggers*, which is manifestly the case. Besides, if the tack be lashed to the stay, much of the difficulty usually met with, in clearing the wreck of a broken jib-boom, will be removed.

## CLEWLINES.

In this article it is thought proper to class all the running-gear partaking of the character of clewlines, as clew-garnets, clew-ropes, and clew-jiggers, giving to each a subordinate head, for ready reference.

CLEW-GARNETS.—These are used only on the courses. The standing-parts are hitched to a thimble at each side of the slings of the lower-yard, for that purpose, and (best if) rove through "secret-blocks"* at the clews of the sail; then back to their respective leading-blocks underneath the yard, (*inside* of the standing-parts,) and lastly to the deck.

TOPSAIL CLEWLINES.—These are best if fitted like the clew-garnets with secret-blocks, and rove through the forward sheeves of the quarter-blocks "via" the lubber's-hole to the deck. In many vessels, however, the method of a whip and pendant is preferred—the former (of *double* the sized rope for the ordinary clewline) being rove through the quarter-block, and attached to the clew-cringle with sister-hooks; while the parts of the whip (but *half* the size) reeving through a block, spliced into the end of the pendant, are led through the lubber's-hole to the deck, and separated widely from each other, on account of the liability to become "hawser-laid."

TOP-GALLANT AND ROYAL CLEWLINES.—These are both single, and connected to the clews of the sails by sister-hooks, and rove through the quarter-blocks of their respective yards, and thence to the deck by way of the lubber's-hole; although in the naval service the royal clewlines do not extend below the top, being rove through fair-leaders on the topmast shrouds, alongside of the sheets.

LOWER STUDDING-SAIL CLEWLINES.—These are simply hitched to the clews, and reeving *abaft* the sail, through small single blocks on the inner end of each lower

* These are an admirable invention, consisting of a sheeve enveloped in a shell, and having holes in one extremity large enough to receive the rope—a plan which precludes the possibility of jambing the reef-points, in hauling up the clews.

studding-sail-yard, are thence led in-board, to a block hooked to the forward futtock-plate.

Fore and Main Clew-jiggers.—These each consist of a purchase (as the term implies) of single blocks, hooked to the clews of the courses, and to eye-bolts underneath the forward part of the tops. In furling sails they are found very useful, for rousing the clews and leeches up forward of the yard; while they also serve the purpose of *inner* halliards for the lower studding-sails, and are often employed as yard-arm jiggers in bending, or reefing.

Topsail Clew-ropes.—These are an essential requisite in scudding, to clew up the sail, in the event of being caught aback, as also in furling. They usually consist of a pendant and whip—the former attached to the clew-cringle on the *forward* side of the sail, and rove through a block at each side of the topmast, under the eyes of the rigging; the whip reeving through a block spliced into the end of the pendant, and having both parts led to the deck, *via* the lubber's-hole.

Note.—In the frigate "Cumberland" the buntlines were double, and the *outer* legs (in clewing up the sail for furling, or what not,) were untoggled, and connected to the clew-cringles, in lieu of extra clew-ropes—a plan which answered every purpose.

## BUNTLINES.

Fore and Main Buntlines.—The neatest and best plan for fitting these (in a large ship—for example, a frigate) is as follows: Through a *double* block hooked at each side of the lower cap, and through two short leaden pipes, inserted between the tressle-trees and pigeon-hole, reeve both ends of each buntline, from *aft*, down forward of the sail to the foot-rope, where they are connected by toggles; having the bight of the middle part (to which a single whip leading through the lubber's-hole to the deck is attached) abaft the block at the cap. The other is rove in a similar manner. But in small vessels, where single buntlines are used, the cap-blocks are single also, and *one* leg only, is toggled to the foot-rope of the sail, some distance out on each side of the midship seam. The advantage of this plan is, that it enables us to rouse the buntlines up *higher;* while the objection to fitting the *main* by this method consists in the fact of crowding too many ropes together—a principle which should never be lost sight of in the reeving of running gear.

Note.—If it is deemed preferable to reeve the *main* buntlines, with the bight forward, through *shoe*-blocks between the stays, the tendency to become "cable-laid" can be obviated entirely, by having the *buntline* of *left*-hand rope, and the *whip* of *right*-hand.

Topsail Buntlines.—These are generally single, and the *fore* rove through the *lower* sheeves of fiddle-blocks* under the eyes of the topmast rigging—thence forward through the thimbles of a span, hitched around the breech of the tye-block, and down to the foot-rope of the sail, where they are connected by toggles—the hauling-part extending to the deck through the lubber's-hole.

* The *main* and *mizen* topsail buntlines reeve through cheek-sheeves in the fore part of the upper tressle-trees, or single blocks, at each side of the heel of the top-gallant-mast.

Note.—In many vessels the buntlines are fitted with whips, and are often spliced into short spans, which toggle to the foot of the sail, at each side of the midship seam.

Top-gallant Buntlines.—These consist of a single "leg," rove from *aft*, through a single block, under the eyes of the top-gallant rigging, (that for the *fore* on the *opposite* side of the flying-jib halliards,) and are spliced around the thimble of a span, toggled to the foot of the sail, about halfway in from the clew, at each side of the midship seam—the hauling-part leading to the top in men-of-war, and in merchant vessels to the deck.

Note.—A good plan is to connect it also with a span on the leech, about halfway down from the head-cringle, which (when the sail is clewed up) leaves it ready for furling.

## BOWLINES.

Fore Bowlines.—These are simply toggled to the bridles, on the foresail, and led in-board to the forecastle through blocks seized to the fore-stay straps.

Main Bowlines—Consist of a whip and pendant—the latter reeving through the thimble in the bridle, and belayed to the fore bitts; and the former passing through a block in the end of the pendant led well forward—the standing-part of the whip being secured to an eye-bolt at the fore fife-rail, and the reeving end over a pin in the side rack. In tacking, when it is required to let go the main bowline, the standing-part of the pendant is cast off, and the whole shifted to the opposite side, ready for reeving.

Top-Bowlines.—The *fore* toggle to the bridles, and lead forward through blocks strapped to each side of the bowsprit-cap, and back, in-board, to the forecastle. The *main* reeve through single blocks, connected to bolts in the after rim of the fore-top, and thence to the deck; and the *mizen* through the outer sheeves of the brace-blocks on the mainmast.

Top-gallant Bowlines.—The *fore* reeve through blocks seized to the jib-guys, and thence in-board to the forecastle. The *main*, through the outside sheeves in the after-chock of the fore-topmast cross-trees; and the *mizen*, through the outer sheeves of their respective brace-blocks, to the deck.

Royal Bowlines.—The *fore*, after being toggled to a *becket* on the leeches of the sail, are rove through thimbles on the royal stay about two or three fathoms from the *nip*, and thence through others on the guys, in-board to the forecastle. The *main* are rove through thimbles seized to the after-part of the fore-top-gallant funnel, and led from thence to the fore-top; while the *mizen* reeve through the outer sheeves of their brace-blocks, like the top-gallant bowlines, and reach to the top also.

Note.—In the merchant service, top-gallant and royal bowlines are invariably dispensed with as "extravagant superfluities."

## DOWN-HAULS.

Topmast-staysail, Jib, and Flying-jib Down-hauls.—These are each bent to the head-cringle of their respective sails, and after being rove through the hanks, and a single-block, seized to the nip of the stay, are then led in-board on the forecastle.

Studding-sail Down-hauls.—That for the *topmast* studding-sail is bent to the outer end of the yard-arm, and rove from thence through a thimble on the leech to the down-haul block at the tack, leading on deck across the forecastle to the opposite side. That for the *top-gallant* studding-sail is merely bent to the inner yard-arm of the sail, and led abaft all to the top.

Gaff-topsail Down-haul (and Clewline.)—This is led from the after-clew of the sail (to which it is bent) through a single block at the head of the sail, and thence through the hanks on the mast down to the deck.

## OUT-HAULS.

Spanker Out-haul.—Vide Ibid. Booms.

Lower Studding-sail Out-haul.—This is clinched, or connected by sister-hooks, to the outer clew of the sail, and led through a single block, put over the boom with a rope-strap, either abaft, to a sheeve above that for the guy in the bulwarks, or in-board along the boom, to the forecastle.

Gaff-topsail Out-haul.—This is hitched to the clew of the sail, and rove through a sheeve at the gaff-end, down to the deck, where it is belayed to a cleat on the boom.

Trysail Out-hauls.—These are used only on board of those vessels where the trysails are set and taken in on the gaff. They are always single, and attached to the outer head-cringle of the sail, being rove through a sheeve in the gaff-end to a leader strapped to the jaws, and having a whip, which is led thence to the deck. The *in-haul* is rove through the hanks on the head of the sail to a single block at the jaws also, but on the opposite side.

## REEF-TACKLES.

Topsail Reef-tackles.—In the navy, they usually consist of a *hide* pendant, clinched to the cringle, on the leech of the sail below the close-reef-band, and lead upward through the *outer* yard-arm sheeve, to the lower block of the top-burton, which is hooked to a thimble spliced into the reeving end of the pendant; the hoisting part of the burton-fall leading through the lubber's-hole to the deck. In the merchant service, however, where burton-pendants are unknown, and where the

burton itself is often required for some other purpose, the reef-tackles are fitted thus: The standing-part of the pendant is spliced to the strap of a block toggled on the leech of the sail, below the close-reef-band—thence led upward through the forward sheeve of a double block on the pacific-iron—down through the block on the leech; up to the remaining sheeve of the double block, and so to the after sheeve of the quarter-block, and lastly, through the lubber's-hole to the *side* rack on deck.

Fore and Main Reef-pendants are simply clinched to the cringle, and rove through the outer yard-arm sheeve, or a block placed temporarily over the pacific-iron, being hauled up by means of the clew-jigger, hooked to a thimble in the end, and a strap around the forward futtock-plate. In merchantmen they are often led through the after sheeve of the quarter-block, which is double, and roused up by a deck jigger attached to the end; and sometimes led like those for the topsails.

Boom-mainsail Reef-tackle.—Vide Ibid. Booms.

## LEECH-LINES.

These are mostly confined to the courses, and those on the *forward* side of the sail are clinched to the leech—the *outer* one about one-third down from the head-earing cringle, and the inner one about two-thirds—and thence rove up through leading blocks on the bending jack-stay* to the inner and outer sheeves (respectively) of a double block, strapped into the end of a long pendant, hooked at each side of the lower cap—the hauling-part of the leech-line reeving through fair leaders on the lower rigging to the *side* rack, on deck. The *after* ones are clinched to the sail in like manner, at the same points, but rove *abaft* through single blocks on the lower yard (corresponding with the position of those for the forward leech-lines,) to double blocks at the slings, and thence on deck to the topsail-sheet bitts.

Note.—In large ships they are sometimes temporarily rove on the topsail-yards (through tail-blocks on the forward swifters) for furling sails, where the leeches are heavy, and clew-ropes are not used.

## BRAILS.

Spanker and Trysail Brails.—These are middled, and the bight secured to their respective eyelet-holes on the leech of the sail by cross-seizings—the *throat* brails reeving through cheek-sheeves on the inner end of the gaff at each side, and the *foot* brails through single blocks seized to the hanks on the trysail-mast.

Jib Brails.—These are fitted in the same manner, and led in-board, except being rove through single blocks secured at each side on the luff, and through leaders between the guys and boom.

* These blocks should be so placed that the leech of the sails will be taut along the yard when hauled up; and fitted with straps, which permit them to hang about a foot below the yard—a plan obviating the necessity of attending the leech-lines in bracing up.

### SLAB-LINES.

These are peculiar to the courses, and spliced into a thimble on a span toggled to the foot-rope at each side of the midship seam, and rove (abaft the sail) up through a single block, seized to the sling-band of the lower yard, or the span lashing of the quarter-blocks, and thence to the deck.

### GUYS.

Lower-boom Guys.—When double, the standing-part of the *forward* one is put over the end of the whisker (when whiskers are used) *after* the jumper-brace, and rove through a single block on the boom, and back to another bolted to the bowsprit cap; the hauling-part being led in-board to the forecastle. When single, as in the merchant service, they connect to the boom by sister-hooks, and the block is dispensed with. The *after* guys are rove in the same manner, except abaft to a bolt and sheeve in each side of the bulwarks, just forward of the gangway.

Spanker-boom Guys.—Vide Ibid. Sheets.

### BUNT-JIGGERS.

These are indispensable helpmates in handling the square sails, and are usually fitted thus: Those for the courses (though more properly bunt-*ropes* than jiggers) usually consist of a pendant, which is rove through a single block hooked to one of the upper links of the lower yard-slings, having sister-hooks in one end, (by which it is connected to the glut on the sail,) and a whip on the other, leading to the deck. The *topsail* bunt-jiggers (of which there are two to each sail, a *long* and *short* one) consist of gun-tackle purchases, corresponding in length to these distinctions, hooked to a bolt in the topmast tressle-trees, at each side of the top-gallant-mast, and to the upper and lower gluts of the sail—the hauling-parts of both jiggers leading to the top. In the merchant service, however, where (as we have before had occasion to remark,) economy is the secret spring of all action and enterprise, in lieu of using two separate jiggers to rouse up the bunt, one is made to serve the purpose of both, by having a pendant spliced into the strap of the upper block, and reeving through a single one on the tressle-tree to the top. In the event, then, of requiring a long bunt-jigger—when, for example, the sail is wet and heavy—it is only necessary to ease off the pendant in the top, which permits the purchase to reach any distance. Again, when the short jigger is requisite, take to the slack of the pendant, and round up the jigger, holding the sail up on the yard, until the lower block can be hooked to the second glut.

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As in all the *unwritten* sciences, the practical application of an important principle in seamanship, like that of which we have just been treating, is accompanied by an infinite number of *traditionary* precepts (so to speak) hoarded up in the mind

of the practitioner. From these a few have been selected, which are offered as a concluding paragraph to this article—*not*, however, as infallible rules, attested by all the fluctuating circumstances of legitimate experiment, but rather as "helps and hints" in a professional dilemma.

Blocks.*—All those for *general* purposes should be in length *three* times the circumference of the rope rove in them; an exception to this, however, is met with in *clew*-blocks for the courses and topsails, which should be in length, but *once* the circumference of the required tack, or sheet.

*Quarter-blocks*, for the lower and topsail yards, &c., should be *twice* the circumference of the sheet that reeves through them.

*Brace* and *purchase* blocks, as they require a good sweep, ought to be in length *four* times the circumference of the rope. If attention is paid to this, the *blocks will give the size of the rope*, and conversely, the *rope the size of the blocks*.

Braces, Studding-sail Gear, &c.—Turn half the length of the *main*-yard into fathoms, and calculate as follows:

7 times half the length = the fore-brace.
6 " " " = the main-brace = fore-topsail brace.
5 " " " = the main-topsail brace.
4 " " " = the cross-jack brace=mizen-topsail brace.

*Top-gallant* braces (if double) should be of the same length as their respective topsail braces. If single, the same length, but *minus* the distance between the masts, (to which they lead,) and half the length of the top-gallant-yard.

The *size* of braces can be approximated to very nearly, by allowing one inch for every 18 feet of the yard in length.

*Lower studding-sail halliards* = the mean length of the fore and fore-topsail braces.

*Topmast studding-sail halliards* = fore-topsail brace = topsail-halliards, and sufficient over for grommet-straps to the blocks.

*Topsail-tyes* = length of their respective lower yards; and should be double the size of the halliards, for if the rope is doubled in size, it will give *three* times the weight, and consequently the strength.

Seizings.—*Eye* do. for 11 inch. rope, 21 thread; *Quarter* do. 15 thread.

" " 10 " " 18 " " " 12 "
" " $8\frac{1}{2}$ to 8 " 15 " " " 9 "
" " 7 " " 12 " " " 6 "

* In the merchant service, blocks fitted with *friction* rollers have been *universally* introduced, and as a consequence, it is a well-established fact that the number of men formerly required to man a vessel has been reduced nearly in the ratio of the decrease of friction. Yet, strange to say, this invention, tending so much to diminish the labor and requisite physical force, is scarcely known in the naval service, except from "hear-say evidence;" which, by-the-by, appears to be excluded with as much repugnance, as in any case of criminal law. And what's the result? That a merchant vessel, measured in *all* her equipments by the *universal* (and often *mean* and scanty) length of an individual *purse*, with a handful of men upon her decks, is frequently manœuvred with as much facility as a man-of-war of equal tonnage, having *twenty times* the *personnel*, and replete with all the essential requisites of efficiency and discipline! And why? Because her spars and rigging are *necessarily*, in a great proportion, heavier, and the sheeve of *every* block on board, to use a vulgar phrase, "turns as hard as the bolts of Newgate."

Gun Gear.—In the absence of a better, the following "rule of thumb" will be found to answer for all practical purposes: *Breechings* should be *three* times the length of the gun, if fitted with shackles; but where they clinch or knot outside, (an old and *senseless* plan,) the thickness of the bulwarks must be added thereto.

In calculating the quantity of rope required for the *side and train tackles* of a battery, allow *five* times the length of the gun for each purchase of double and single blocks; and for every one with two single blocks, *four* times that quantity. This will afford sufficient for grommet-straps to the blocks. But where they are already fitted, allow *four* times the length of the gun for the first case, and *three* times for the second.

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## FITTING AND BENDING SAILS.

Prior to the performance of this important feature in the equipment, the sails should be carefully examined, in order to supply any omissions of the sailmaker; and it may not be amiss to name the points, clews, cringles, bridles, thimbles, beckets, eyelets, toggles, and gluts, as parts necessary to include in this precautionary scrutiny. In addition to which, the fore and aft sails must be prepared with hanks, brail-blocks, lacings and lashings, and the square sails with earings and rope-bands. The *earings* (divided into two classes of reef and head-earings) should be spliced into eyelets, just below their respective cringles, with an eye sufficiently long to take one outer and one inner turn, which are consequently equal to two *single* outer and inner turns. The reeving-ends of the *reef*-earings (which are whipped) being made fast to the cringles of the next band (*above*) with a bowline hitch: for example, that for the close-reef to the third; the third to the second, and so on; the object of which, is to place each earing within the reach of the men in reefing; a simple measure, but nevertheless of some magnitude in practice. The *rope-bands*, consisting of two-yarn foxes, are middled, and secured to the head-rope, by thrusting *one* end through the bight, which is first passed through the eyelet from the *fore* side of the sail, and hauled taut. The next consideration is to place the *gaskets* on the yards. These are classed as bunt, yard-arm, and sea gaskets, and are usually made of plaited yarns. Those for the *bunt*, consist (in the navy) of two single legs—one on each side of the slings, varying from two to three inches in width, and fitted with a thimble in one end, by which it is secured to the *bending* jack-stay with a permanent seizing—the other extremity having a laniard, which is hitched to the opposite quarter of the yard on top; the gaskets crossing each other on the bunt when the sail is furled. This plan, however, is not so common in the merchant service. There the midship-gasket more generally consists of a skeleton triangle of sennet, with a thimble in each corner—those at the base being secured to the jack-stay by seizings, and the upper one (which is fitted with a laniard,) hitched to the tye or yard-slings, as the case may be. The *yard-arm* gaskets are made of sennet also, and fitted with a thimble, or eye, in one end, and the other tapering, and secured at equal distances (generally about every third seam) along the yard, *underneath* the jack-stay, by a cross-seizing just below the thimble. The *sea-gaskets*,

or more properly furling-lines, (of which there are two on each arm of the lower and topsail yards,) may be either of sennet or small-sized rope, and of sufficient length to go around booms and all, when furling in heavy weather. These, however, are not necessarily permanent fixtures to the yard, although usually put round it at the outer and inner quarters with a running-eye, and the surplus end bighted up with frapping turns, and thrown forward of the sail, at sea.

In order to illustrate more fully the minutiæ of bending sails, it is thought proper to bend each separately, and in the order of its size and importance, without regard to the usual routine, even at the risk of incurring censure from the *critiques* of the "manger" for that repetition of terms and technicalities, so characteristic of professional books.

## COURSES.

Stretch the head of the sail across the deck forward of the mast, having the *roping* on the *under side*, and gather the leeches up in bights, by bringing the reef-bands successively to the head-rope, which will leave all parts clear for bending on the rigging. Toggle the buntlines to the foot-rope at each side of the midship-seam, and clinch the leech-lines to their cringles, stopping both to the head of the sail—the former to the eyelet of the middle rope-band, and the latter in the wake of their leading-blocks. Hook the clew-jiggers* from straps around the pacific-iron to the first reef-cringles, hitching the head-earing to the standing-part. Shackle or *seize*† on the clew-garnet blocks (with the ropes rove) to the after-part, passing them *under* the sail. Send hands on the lower yards—trice up the booms—man the gear and sway aloft, merely gathering up the slack of the clew-garnets. When high enough, (i. e. when the centre of the sails reaches the centre of the yard,) bring to, cut the buntline and leech-line stops, and make fast the midship rope-band, together with three or four others at each side of it, by passing the short ends *under* the jack-stay from *forward*, *aft*, and the long ones *over* and *under*, from *aft*, forward—thence back through the eyelets, and square-knot them on top. Haul the sail out until the head-rope is taut along the yard, and pass two or three turns of the earing through the thimble of its strap, and if the sail is new, let the men ride it down in order to stretch the head-rope, and bring the cringle and thimble as nearly together as possible. Then pass the earing afresh, and for a full due—viz. *two* turns from out, in, through the thimble and back to the cringle, expending the end leading last from the latter, *over* and *under* the yard, *inside* of the head-earing strap, and secure it by hitches around the turns *first* taken. Now make fast the remaining rope-bands in the same manner as the midship ones, and clinch or reeve the reef-

* Where the reef-pendants (or properly tackles) are rove, as in the merchant service, viz. from the yard, through a block toggled to a short bridle on the leech, below the last reef-band, the clew-jiggers may be dispensed with, and the sail hauled out to the yard-arms by these pendants, which in this case should be rove on deck, and the head-earing cringle stopped to the standing-part. This plan, (which was adopted on board of the "Columbus," 74,) apart from the facility it affords in reefing, will be found serviceable in bending and unbending the sail, whenever it may be essential to perform that evolution.

† In lieu of having the shackle large enough to receive the clew-garnet block, with those for the tack and sheet, as recommended in the note on page 56, the former is sometimes *seized* to the clew as here stated, for the reason, that if the shackle should part or unkey, the sail may still be hauled up by the clew-garnet.

pendants, as the case may be. Haul up the clew-garnets snugly, and shift the yard-arm jiggers to the forward futtock-plate, for the clew-blocks, (through which the tacks and sheets are rove,) and shackle them to the cringles. Lastly, slack down and overhaul the gear, and set the sail to ascertain its fit, and if all is rove right—then clew up—hook the bunt-jigger, pass in the leeches, and furl. (Vide Ibid. Part II. Evolutions.)

## TOPSAILS.

Having prepared the sails for bending, and supplied any deficiencies which may be requisite, place them on deck forward of their respective masts, rolled up on the *fore* part,* and secured by three or four rope-yarn stops on each side, having the first reef and head cringles together, and the foot-rope clear for bending on the rigging. Hook the sail-tackle† from a strap on the topmast-stay collar, to *one* bight of a stout pair of slings, passed around the centre of the sail, and *seize* the other to the *back* of the *hook*. Overhaul the sheets and the reef-pendants, bringing the bending-ends of both into the top, and have the bowlines, buntlines, and clewlines ready for toggling, and bending to the sail. Send hands aloft on the yards; man the tackle—trice up the booms, and sway away. When the sail rises above the top, cut the stops; shackle or clinch the sheets and reef-pendants, stopping the head-cringle to the latter, into the thimbles of which, hook the top-burtons.‡ Hook also the clewlines (or if double, *lash* on their blocks) to the clew-beckets, and toggle the buntlines and bowlines to the foot-rope and bridles respectively. Now man the burtons, and sway up on the tackle, until the centre of the sail reaches the centre of the yard, then pass the middle rope-bands; rouse out the head-cringles, cutting the seizing of the reef-pendants, and that of the slings around the sail; at the same time gathering up the slack of the buntlines and clewlines. If requisite, ride down the head-rope, and pass the earings, (for a full due,) and the remaining rope-bands, as in the case previously stated. Then unhook the burtons and the tackle from the stay—overhaul the gear; sheet home the clews; down booms, and hoist the sail up to a taut leech, both with and without the reefs; after which, lower the halliards; clew up—hook the bunt-jiggers, and furl.

## JIB.

This sail, as with those previously mentioned, requires certain equipments, not strictly within the contract of the sailmaker; and as such, mingled with the varied and comprehensive duties of the seaman. Among these "extrinsic requisites," we may note the lashing on of the *bonnet, hanks,* and *brails.* The former, although confined chiefly to the naval service, and to small craft, as pilot-boats and sloops, (in which a staysail is not used,) is secured to the jib as follows, by a lacing spliced

* The reason for making the sail up on the fore part is to cause it to fall *forward* and clear of the top when cast loose from the slings.

† This consists of a long stout burton, for the purpose of bending sails, and is allowed to all the vessels of the naval service.

‡ On board of merchantmen, in lieu of the burtons, the sail is hauled out by the reef-tackles alone, the head-cringles being stopped to the standing-part, as in the case of the courses.

into the tack-cringle of the sail: Pass a *bight* of the lacing (from *starboard* to *port*, for example) through the forward eyelet of the bonnet, and up through the corresponding one of the jib, from *port* to *starboard;* then reeve the *end* through the bight, and haul it taut; after which, form another bight as before, and proceed in the same manner, reeving it alternately in the eyelet of the bonnet, and that of the jib, until all are included, and secure the end by two half-hitches to the cringle of the leech.

The *hanks,* which usually consist of stout thimbles sufficiently large to traverse freely up and down the stay, are attached to the luff by good-sized foxes of spun-yarn, rove through the eyelets, and passed around the hanks on *both* ends, which (being of sufficient length to fill the score) are knotted on the after side, and secured in frapping turns, between the luff and hanks.

The *brails* (though previously described in the article on "Running-rigging") are simply middled and secured to the leech eyelet with a cross-seizing; after which, they are rove forward through single blocks, fitted with a short span, and seized to an eyelet, or cringle on the luff, for that purpose. In merchantmen, however, brails are seldom used on the jib; and many seamen, who deem them "superfluous gear," assert that the chafe induced by brailing up is sufficient of itself to exclude them from the calendar of "necessities," and to even justify the hauling down and hoisting of the sail, whenever it may be desirable to dispense with it, or essential to shift the sheet. (*Quad erat demonstrandum.*)

Now in order to bend the jib, cast off and unreeve the stay from the boom, (having a marrying-line bent to the becket,) and bring it in on the forecastle, or either side of the topmast-stays. Make the sail up in *bights* on the *foot,* in such a manner that the hanks shall stand one *above* the other, and reeve the stay *down* through them, and the down-haul *up,* hitching the latter to the head-cringle of the sail, and seizing both to the lower hank, just above the *nip.* Reeve the brails, and pass them (after the manner of a lashing) around the sail, and hook the halliards into the bights, swaying it up above the bulwarks. Re-bend the marrying-line, (the hauling-end of which is also in-board,) and man it, together with the down-haul, rousing out the jib, until the nip comes to the sheeve in the boom. Then clap on the luff-tackles, and set up the stay, for a full due; cast off the brails, and unhook and *re*-hook the halliards to the head-cringle—reeving the former through their leading-blocks (between the guys) in-board to the forecastle. Seize on the sheet-pendants to the clew; man the halliards; cut the racking of the lower hank and down-haul, (passing the latter through its block, which must be seized to the nip,) and hoist the sail up to a taut luff. Then lash the tack to the stay; trim aft the sheets; work the brails, to ascertain if all is rove right, and haul down and furl the sail.

## TOPMAST-STAYSAIL.

This sail is made up like the jib, viz., with the eyelets and the head, tack, and clew cringles clear for bending; and is swayed out on the bowsprit, by means of the down-haul and halliards—the latter being hooked to a stout strap, passed around the body of the sail, in lieu of brails, (of which there are none.) The hanks, which are either small wooden hoops, or horse-shoe thimbles, having small eyes at each side of the opening, are secured to the eyelets by means of rope-yarn foxes. In the merchant

service, where the topmast-stays are fitted to go around the bowsprit, as alluded to in the article on "Standing-rigging," the two are seized together at the tack of the staysail, and the hanks made large enough to traverse on both.

## FLYING-JIB.

The routine of bending, as stated in the case of the jib, answers for the flying-jib; there being a few peculiarities only, to which it is perhaps well to refer, viz., it has neither brails nor bonnet; and in bending, the sail should be sent out on the *starboard* side of the bowsprit, on account of the inclination of the wythe (and consequently the boom) to that side.

NOTE.—Much of the labor incident to the bending of the sail, may be obviated by fitting it with a lacing in lieu of hanks,—a plan which is infinitely preferable for neatness, and which saves the necessity of turning out the stay. This lacing is hitched to the upper eyelet, and rove in every alternate one to the tack-cringle, where it is secured—leaving between the eyelets a surplus bight, which (when it is required to bend the sail) is passed around the stay, *against the lay*, and seized to the eyelet omitted in reeving.

While writing of this sail, it is thought proper to call the attention of the reader to a late method of fitting the sheets with two single blocks (through which they are rove) at the clew, and the standing-parts made fast to the lower end of the dolphin-striker. This plan, it will be perceived, corresponds, in some measure, with the principle laid down in the note on page 57, in reference to the position of the bolts.

## ROYALS AND TOP-GALLANT SAILS.

In reference to these sails, little need be said, (except that they should be always bent on deck, on account of the difficulty of hauling out by hand,) as the earings and rope-bands are passed like those for the courses and topsails; the buntlines, bowlines, clewlines, and sheets, being bent after the yard is crossed. If, however, it should be necessary to bend the *top-gallant*-sail aloft, as is frequently the case on board of merchant ships, it may be sent up by the yard-rope, and the head-cringles hauled out by means of the top-gallant studding-sail halliards.

NOTE.—In furling either a royal or top-gallant sail, it should be made up with a *long, taut bunt*, and the clews "tucked in," to avoid tearing the sail in its upward or downward passage.

## FORE AND AFT SAILS.

The manner of bending these sails is so nearly identical, that to save room and avoid repetition, it is deemed proper to class the spanker and trysails under this head, and to bend them in the old-fashioned way—referring in the end to the different methods of equipment, and to the peculiarities of each.

In the making up, there appears to be no particular rule of guidance, except that each sail must be placed fore and aft, under its respective gaff, (which should be

lowered down for the purpose,) having the head and luff clear for bending. Reeve the brails in their blocks and sheeves, and pass the sail through the bights, rousing up and securing the *knock* (or throat) earing, which is usually passed around the gaff, and through the cringle. Although a better plan, and one frequently adopted in the merchant service, is, through a score (cut fore and aft in the gaff, directly between the jaws) and an eye-bolt on the *upper* side—the end being secured by hitches around the turns, of which there are generally *three*. Now haul the head of the sail taut along the gaff, using a jigger for the purpose, if requisite, and pass the peak-earing, (consisting of small-sized ratlin stuff well stretched,) which is taken (in *two* turns) from the cringle over the gaff, *abaft* a cleat on the upper side, and back to the cringle; expending the remaining part through the cringle, and around the gaff *inside* of the cleat: after which, take two half-hitches around the outside turns underneath, to bind all parts together, and stop the end. Seize on the brails to their eyelets on the leech, (or, if the sailmaker should have omitted to work them, the point for those of the throat and peak may be obtained by bringing the leech in taut along the gaff, and marking the contact of the blocks and sheeves;) then reeve them, and pass the head-lacing from *aft, forward*, through the eyelets, and around the gaff, (taking a marlin-hitch at each,) on the upper side of the latter. Lastly, man the halliards, keeping the peak a little in advance of the throat, (in order to hoist easier,) and seize the luff to the hoops (or hanks) on the trysail-mast,* as the sail goes up, by passing the rope-bands (which are middled in the eyelets) on both ends, and knot them in frapping-turns, between the luff and hanks. As a *finale*, (if the sail is a spanker,) clinch, or hook the out-haul to the clew-cringle, and reeve it in its sheeve. The tack is then either lashed to a bolt on the boom, close to the jaws, or fitted with a small gun-tackle purchase, hooked to the deck, and brought down taut along the trysail-mast.

Note.—In vessels where the spanker and trysails are fitted to traverse on a stationary gaff, as referred to on page 47, they are usually sent up for bending by means of the in-and-out haulers, stopped to the throat and peak-earing cringles, and rove in their respective leading sheeves. Brails are then dispensed with, except one for the foot; and the head of the sail is secured to the hanks on the gaff, as in the case previously stated—the luff being seized to the batten or jackstay, with spun-yarn foxes.

## BOOM-MAINSAIL.

The routine, as stated in the preceding article, will be found to answer for this sail, there being, however, necessarily some slight exceptions, viz., the omission of brails; and in lieu of an out-haul, the clew is shackled to a span on the boom. Another distinction is, that the last three or four hanks are omitted, and their absence supplied with a lacing, passed *before* the mast, and through the eyelets instead of a round turn—which latter plan, though frequently practised, is nevertheless ill-suited to tricing up the tack, on account of binding.

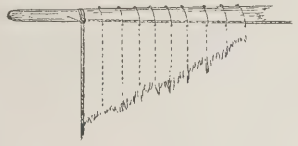
Note.—A small single block should be seized to the middle hank on the mast, for the tack tricing-line.

* To the *travellers*, if fitted railway fashion.

### STUDDING-SAILS.

The following method of bending these sails (though requiring more time than is usually bestowed) will be found the neatest and best, and in the end to fulfil all the conditions sought for, by extra pains and care—the sum and substance of which, may be reduced to the simple consideration of having the roping of the sail on the *after* side of the yard in lieu of underneath, and secured in such a manner as to preclude the possibility of its "bagging down."

Fig. 24.



The outer earings, which are spliced into the cringles with a short eye, are passed through holes bored in the extremities of the yard, from the after side—thence back through the cringle and over the yard, *inside* of the hole, until three or four turns are taken, when the end is hitched through the cringle, and around the single part, as represented in the accompanying figure. The sail is then brought taut along the yard—the inner earing passed in the same manner, and the head-rope secured by a neat lacing of housline, rove around the yard and through the eyelets with a marline-hitch on top, at each of the latter. Lastly, the gear, or at least that portion of it which includes the sheets and down-haul, is bent after the manner described in "Running-rigging," and the sail made up, on the after side, by bighting the leeches towards the head, and running the gear along the yard.

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In conclusion, many may find fault with the absence of a regular routine of bending the sails together, but this has been omitted as superfluous, in order to state clearly every point in reference to the subject; because it is a knowledge of the *minor features* alone, in any profession, which constitutes the *sum totum* of successful practice. And it seems but reasonable to maintain, that the mind, which is thoroughly cognizant of *every* peculiarity in the minutiæ of a branch like this, (where there is a mutual and characteristic dependence,) can never be at a loss to adapt its faculties to a combination of that knowledge in *one* system of practical application.

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## GROUND TACKLING.

Under this general technical term is comprehended all those multifarious appurtenances to the anchors and cables of a ship, known as stoppers, nippers, messengers, hook-ropes, clear-hawse pendants, deck-tackles, cat-falls, fish-davits, buoys, chain-

hooks, compressors, &c. And for the sake of greater perspicuity, it will be necessary to class each one under a separate subordinate head, in the order of its importance; and to accompany each classification with a statement of its use, and method of equipment, both in the navy and mercantile marine.

## CABLES.

The advantage resulting from the introduction of iron, as a substitute for rope, in the equipment of vessels, is nowhere so forcibly illustrated as in the use of *chain*-cables; and perhaps the best evidence which can be adduced of their superiority over the hempen ones of the "dark-ages," is the universality of their adoption. Under these circumstances, little need be said of the latter, except so far as it may be necessary to refer to some important feature, resulting from that connection always existing between an original and its successor.

The first consideration is, that the chains should be clearly and distinctly marked —for although having a shackle at every fifteen fathoms, and a swivel at the forty-fifth, or sixtieth, (depending upon the length,) it is essential to have not only these distinguished by some mark, but other points of the cable also, in order to know at all times, while at anchor, the amount by which the ship is riding. In the naval service various methods have been adopted, but as yet no *perfect* system arrived at, beyond placing small wire rings around the *stretchers*. *Totten*, who is perhaps the best criterion, thus states the routine which is pursued in the United States Navy: "After the first shackle, which will be fifteen fathoms from the ring of the anchor, measure off five fathoms, and mark with two turns of wire for the twenty-fathom mark, one for the twenty-five, three for the thirty, and so on."

In the merchant service, however, even this system, replete as it is with imperfections, is not practised; and naturally enough, where the *chronometer* is sometimes set by a foundry-bell, or an evening-gun,* the amount of chain in the hawse is invariably calculated by that *anti*-mathematical system of *guessing* so available to Yankees in a "tight-place."

Having marked the chains, proceed to get them on board. The manner of doing this, however, will depend in a great measure on the position of the ship. If moored in the stream, as we have thus far supposed, bring them alongside in a lighter or scow, (ranged fore and aft, in order to divide the pressure equally upon the deck or flooring,) and take them in through the vacant hawse-holes, with the assistance

* This assertion, though somewhat comprehensive in its bearing, is by no means applicable to the whole fraternity of merchant sailors; for the high character and perfection of our commercial marine are an evident contradiction to it, and sufficiently palpable to every one, to confine a statement of this nature within *appropriate* limits. The following dialogue, however, which took place about twilight (*not* a hundred years ago) between the officer of the deck, on board of the frigate C———n, at anchor in Callao Bay, and a *whaling* captain, whose vessel was weighing under the stern of the frigate, will not only serve to illustrate the truth of the remark, but to point out its application:

"Ship ahoy!" bawled the captain.

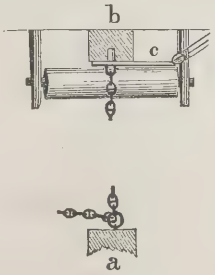
"Halloa! what do you wish, sir?"

"My *ker*nometer's down, and I want to know, stranger, what time you fire that gun of your'n?"

"Eight o'clock, sir," responded the lieutenant, and down popped the "capting" on his "*winding* way," to the delinquent timekeeper of "Frodsham & Co."

of deck-tackles and chain-hooks. If, on the contrary, the vessel should be secured to the wharf, they may be got in either through a plank *shute*, leading from one of the midship ports to the chain-pipe, (in the locker;) or over a half-rounded spar, lashed on top of the gunwale. Prior to the stowage of the chains, however, it becomes necessary to secure the end below, as a preventive from loss, in the event of being unable to check its outward passage in veering; and perhaps the best method for accomplishing this object is the following, which was adopted on board of the frigate "Cumberland:" Through a ring-bolt in the kelson, the end of the chain was rove up to an iron roller, attached to the beams of the lower deck, immediately above—the last link of the chain being curved, in order to fit over a short perpendicular arm on the surface of the roller, which was kept from turning by a check-lever, having a small tackle attached, as represented in the subjoined figure. In the event, then, of having to *slip*, it only became necessary to haul on the jigger, which permitted a revolution of the roller, and disengaged the link from the arm. The sim-

Fig. 25.




plicity and security of this plan cannot fail to strike every intelligent reader. In the merchant service, the usual method of securing the cable is by means of a lashing either through a ring-bolt in the kelson, and the last link, or around the heel of the foremast.*

The stowage of the chains is effected by ranging them *fore and aft*, assisting to do so, if requisite, with a hook-rope, (which is used to form the bights,) and rove through a tail-block in the after-part of the locker. For the stowage of *Hemp Cables* and *Hawsers*, vide Ibid. Part III.

## BENDING HEMP-CABLES.

Reeve the starboard ring-rope (from the block on the anchor-stock) through the ring from *in, out*, having passed the end in through the sheet hawse-hole, and bend it on to the cable with a rolling-hitch, four or five fathoms from the extremity—putting on stops as requisite. Pass the standing-part of the fore-bowline in, and bend it to the cable also, in the same manner. Then with the latter rouse it out, having *slip*-ropes at the fore-tack bumpkin and cat-head, to keep the cable clear of the bow; as also a hand on the bowsprit to cut the stops of the bowline clear, as the cable comes out to the block. Haul the end aft, and through the ring of the

* For many obvious reasons the chain-lockers of merchant vessels are placed well forward, and as near the windlass as possible.

anchor, by means of the ring and slip ropes, (casting off the bowline,) until a portion of the cable equal to the length of the shank is roused through the ring, at which it should be seized—then form the clinch "*with* the sun," having the end *inside*,* and clap on the bends, which consist of ratlin-stuff middled and passed on the bight around both parts of the cable—cutting the stops of the ring-rope, and rendering the cable through the clinch, in order to make it as small as possible to avoid chafe from the shank-square.

The *port* ring-rope is rove in the reverse manner—viz., from *out, in.*†

The following plan for hemp-cables, recommended by Lieut. Fordyce, and practised in the British Navy, will be found to save much of the time and labor incident to the operation of bending, as detailed in the foregoing paragraph: Unlay the strands of the bending-end of the cable about three fathoms, and make a long splice with two of them—keeping in the lay. Then with the remaining strand make an eye-splice to come fair with the bight of the two strands, and get the cable on a stretch—opening well the eyes thus formed with a fid. Tail stuff on to the ends of the eye-splice, and worm it four or five fathoms down the cable, clapping on stops every four feet or so to the end of the worming. Remove the fid, and thrust in an oval cut-thimble large enough to receive the pin of a chain-shackle, having it well tarred and parcelled, and lay a strand of rope in the cut-line, where the two eyes come together, and put on a stout seizing close up to the thimble over strand

Fig. 26.

and all. This is called an "Elliott's-eye," and when the sheet-cable is required for bending, it is simply shackled to a chain length, attached to the anchor in the usual way, either as a permanent fixture or otherwise.

Note.—In shackling chains together, it would be well to remember that the *round* part of the shackle should always be placed *forward*, so as to pass out of the hawse first: by this precaution it can never get foul in running.

## ANCHORS.

The method of getting on board the anchors in merchant vessels, is so nearly similar to that adopted in men-of-war, that it seems scarcely necessary to draw a distinctive line between the practice of both, although the absence of "sheets" in the former, and the necessity of heavier anchors in the latter, (arising from the peculiar design and service of war vessels,) produce a slight difference in the purchases used.

Cat-falls.—These consist of a double, treble, or four-fold purchase, (depending upon the relative size of the vessel and anchor,) rove and fitted as follows: The standing-part of the fall, after being secured to the cat-head either with a running-eye close up to the rail, or by means of a stopper-knot through a hole just forward

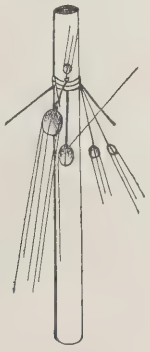
* This is technically termed a jambing clinch—and as it is designed *not* to *slip*, the reason is obvious.

† Much of the misapplication incident to similar expressions, as "in, out," and "out, in," may be obviated, (in this particular case at least,) by remembering that *both* ring-ropes are rove *from port* to *starboard*.

of the sheeves, is passed down through the forward sheeve of the cat-block, (which is iron-bound, and fitted with a hook, large enough to receive the ring of the anchor;) thence up through the corresponding sheeve of the cat-head, and so on alternately to the after sheeve of the latter, from whence it is led in-board through a leaden pipe in the bulwarks, or simply over the rail. In many vessels this is rove in the reverse manner, viz. from aft, forward.

Fish-davits.—In all the vessels of the naval service (above sloops-of-war in size) a perpendicular davit of oak, temporarily stepped in a saucer immediately abaft the bill-board, is employed to fish the anchor, using it on either side. On board of the "Cumberland" this was rigged as follows;* the davit being made with shoulders on the upper end for the gear, and the heel rounded to correspond with the concave mortise of the saucer—in which it was stepped by means of the pendant-tackle, hooked to a strap around the head.

Fig. 27.



1. *Fair-leader.*—This consisted of a stout single block, (for the hauling-part of the fish-purchase,) fitted with a long double strap, which was served and placed over the davit-head first of all.

2. *Guys.*—These, one forward and one aft, were single pieces of heavy rope, going over with round spliced eyes—the former securing to a cleat on the cat-tail, and the latter setting up to a bolt in the fore channels.

3. *Fish-fall.*—This (consisting of a double and single block—the latter fitted with a large iron-hook like that for the cat) was attached to a stout strap around the davit-head, as illustrated in the foregoing figure—the hauling-part of the purchase leading up through the fair-leader, and connected to the lower block of the pendant-tackle, by means of a backwall-hitch.

4. *Topping-lift.*—A small stout jigger, (used to cant the davit in-board or out-board,) hooked to a thimble on the upper extremity, and a strap around the fore-mast, some distance above the deck.

5. *Bill-tackle.*—This, consisting of a similar jigger fitted with a long pendant and eye going over the davit-head, was hooked to one of the lashing-bolts in the bill-port, and used for canting the fish-purchase.

* The rigging of this might be greatly simplified by having a shoulder-band with eye-bolts for the guys and topping-lift.

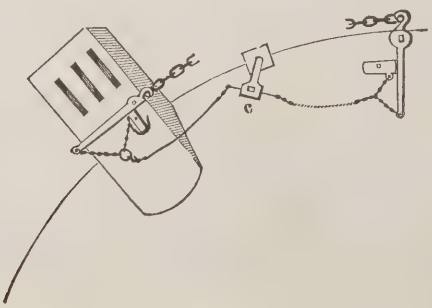
6. *After-tackle.*—This consisted of a jigger also, connected to the davit-head, as in the previous case, and to a bolt in the deck, at the partners of the foremast.

In the smaller class of war vessels, in lieu of a perpendicular davit, a stout spar, (with a sheeve in each end,) placed horizontally athwart the deck, and projecting through the bill-port, is used, having an in-and-out jigger attached to the heel, and the fish-*pendant* (fitted with a stout hook in the lower extremity) led through the outer sheeve of the davit, up to the lower block of the pendant-tackle, by means of which the anchor is fished. On board of merchant ships, a plan differing from both of these is pursued, which saves the necessity of davits, by having a long stout purchase at the fore-topmast-head, hooked into the end of the fish-pendant, which is passed down over the rail, outside of all.

Back-ropes.—These are simply small leading-lines, either grafted or hitched to the back of the cat and fish hooks, and of length sufficient to reach from the rail to the water-line, with ease.

Cat-head and Shank-stoppers.—The following diagram will serve to illustrate a recent invention, by which both the ring-stopper and shank-painter are cast off simultaneously. The former, which is of chain, secured by a stout shackle to the forward side of the cat-head, is passed through the ring of the anchor, (when catted,) and the last link placed over a hinged-shoulder, maintained in an upright position by means of a hook-lever extending across the cat-head. The shank-painter is secured in a similar manner at the bill-port. To each of these a trigger is attached, fitted with a small chain leading in the water-way to the arms of a swivel, worked by means of a bar shipped in the mortise (*c*)—giving it a half turn, either to the right or left, which disengages both stoppers at the same instant.

Fig. 28.




The worth of this invention will be apparent when we consider that in addition to its advantages in letting go the anchor, it admits also of being unshipped, and stowed away when not required for use—in which case the stoppers are belayed around cleats, or timber-heads, and the anchors lashed. The plan hitherto has been, to have the shank and ring stoppers of rope and chain, simply taken over cleats or cavils, and let go by hand, at the conclusion of the words "one—two—*three!*" Subsequently this was modified by the introduction of the triggers, which were (and are now in many vessels) set off by means of a top-mall, and a hand at each. Later

again, however, this was greatly improved by Commodore Jos. Smith of the United States Navy, to whom the addition of the swivel and leading chains is due.*

Having rigged and rove the cat and fish falls, overhaul them down, and prepare for getting up the *bower* anchors, which should be brought under the cat-head in scows, with the crowns aft.† If the chains are already stowed, as we have supposed, rouse up the ends, and pass them out of their respective hawse-holes, (the forward or inside ones,) shackling them at once to the anchors. Hook the cat—man the fall—dropping the scow out of the way, and walk the anchor up—passing the ring-stopper, as the fall comes two blocks.‡ Now rouse in the chains until hand-taut, and mark them in the wake of the hawse-pipe for catting, which "will save much of the customary noise incidental to the cry of cable enough."§ Hook the fish (from *out*, in) to the shank—man the purchase and sway away, until the palm of the upper fluke rests against the rail, or bill-port—then pass the shank-painter, as in the case already stated. The davit having thus performed its office, is unstepped by means of the pendant-tackle—the rigging taken off, and all stowed away.

Finally, bitt the cables by throwing the bight (formed of the slack chain abaft the bitts) over the bitt-head, so that the after part shall lead from the cavil to the locker, *outside* of the other part. In merchant vessels this operation is necessarily quite different, on account of having a windlass; the chain being passed over and around the *welts*, with one and a half, or three turns, as the case may be, prior to bending to the anchor.

Note.—In the new steamers "Atlantic" and "Pacific" the hawse-holes are cut on the main deck, and the chains led by means of iron pipes up to the spar deck, on which they are worked.

We come now to a consideration of sheet-anchors—a subject scarcely concerning the merchant service at all, since they do not fall within the pale of "allowances." In the cases of ordinary practice, the following routine is adopted in the navy: Having the anchors alongside in lighters or scows, with their crowns aft, and the shores and stoppers in readiness, prepare to secure the yards, and reeve the purchases. Supposing it to be the starboard waist anchor, brace the main-yard *up* and the fore-yard *in*, in such a manner as to render the action of the purchases at the stock and crown as nearly vertical as possible. Then top up on the lifts on the side used to give the yards an inclination of about 10° with the horizon. Overhaul and hook both top burtons from the lower and topmast heads respectively, to straps around the yards on the starboard side—one within and one without the anchor-purchase—hauling them taut on deck, as also both lifts and the trusses—observing the precaution that the starboard lifts and burtons bear an equal strain, and that

* This improvement was first put in practice on board of the "Cumberland," at that time bearing the flag of the Commodore, while in command of the Mediterranean Squadron.

† Where anchors are brought alongside in this manner, to be got on board, it must be remembered to stow the *starboard* one on the *port* side of the scow, and *vice versa*.

‡ The stopper is first hauled taut through the ring of the anchor, by means of a jigger, and three turns, one above the other, taken around the timber-head or cleat, and the end stopped to the first turn with a temporary seizing.

§ Glascock's "Manual."

the *opposite* braces are not taut. Lash a large bull's-eye on the *after* side of the yards far enough out to permit the purchases to hang clear of the ship's side, and plumb over the anchor berth. Reeve the pointed ends of the top-pendants up through these, and clinch them over the lower caps, between the doublings of the masts—having the *lower* blocks of the pendant-tackles hooked to the thimble in the extremity of each top-pendant, (hanging about two or three feet below the yard,) so that the hauling-part of the fall shall lead *up*, through a leader lashed on the yard in a line with (and to a block at) the lower cap—thence on deck. Pass stout straps with jambing turns around the crown, and the shank of the anchor near the stock, to which hook the fore and main yard purchases respectively. Rack both parts of the fore-topsail tye aloft, and hook the lower block of the halliards to a strap around the shank, and lashed to a point on the upper arm of the stock about one-third up. Now bend a hawser to the crown, (to weigh the anchor in case of parting the straps,) and man the purchases—keeping a strain on the halliards to cant the stock vertically, and keep the arms in a horizontal position. As soon as the anchor is clear of the lighter, drop her astern, and hook on athwartship tackles to straps around the shank. When high enough, haul over—place the score (in the lower end of the stock) in the bight of the trip-stopper,* rouse the palm in on the gunwale, and lower away—resting the after part of the shank on the trip-shores, which are fitted with a stout hinge in the heel, bolted to the ship's side, permitting them to fall outboard, and bear the anchor clear when let go.

Having thus landed the anchor safely in its berth,† (using a fore-and-aft tackle if requisite,) pass the lashings, consisting of (half-worn) inch rope, on both ends, through span-shackles in the water-way, around the shank, at the stock and crown respectively,‡ covering them, at the conclusion, with canvas, which should be protected from the influence of moisture by a coat of paint or coal-tar. Now shift over the purchases to the opposite side, and secure the yards as before, getting in the other anchor in a similar manner; after which, send down the tackles and burtons —square the yards—cut the racking of the tye aloft—re-hook the halliard-block to the bolt in the channels, and unbend the hawsers from the crown of the anchors.

Note.—The lately invented anchor (with moveable arms, which are attached to the crown by a bolt) is now in frequent use in the merchant service. This possesses many commendable features—among which we may enumerate small stowage; certainty of holding on, (arising from the peculiar position of the fluke in the ground, and the impossibility of fouling the chain;) less danger to the vessel's bottom in driving over in shoal water, than with the ordinary anchor; and last but not least, admitting the possibility of supplying a broken fluke. These are certainly considerations of no little magnitude, and waiving for the present the question of strength, (which appears to be a mooted one among nautical *connoisseurs,*) it may not be invidious to predict a universal adoption of this admirable invention within a limited period.

* This consists of a stout short span of chain secured horizontally by eye-bolts to the side, and is used for the stock to turn upon, and cant the anchor in letting go.

† The position of the sheet-anchors depends upon the peculiar class and construction of the vessel—sometimes in the fore-channels and sometimes in the waist. In reference to the *trim*, this consideration should not be passed over. Vide Ibid. Part III. Stowage.

‡ In the "Cumberland," in addition to the lashings here described, fore and aft ones were used at the stock and crown, from ring-bolts in the fore-channels and waist.

The following "Table showing the size of Cables and Anchors proportioned to the tonnage of vessels," is extracted from the "*Mechanics' Pocket-Book*," a very useful little work by Charles H. Haswell, Esq., Chief Engineer U. S. Navy.

| Tonnage. | Diam. chain in inches. | Wt. Anchor in lbs. | Wt. Chain per fath. |
|---|---|---|---|
| 200 | 1. $\frac{1}{16}$ | 1176 | 60 |
| 240 | 1. $\frac{1}{8}$ | 1400 | 70 |
| 270 | 1. $\frac{3}{16}$ | 1456 | 78 |
| 320 | 1. $\frac{1}{4}$ | 1680 | 86 |
| 360 | 1. $\frac{5}{16}$ | 1904 | 96 |
| 400 | 1. $\frac{3}{8}$ | 2072 | 104 |
| 440 | 1. $\frac{7}{16}$ | 2240 | 115 |
| 480 | 1. $\frac{1}{2}$ | 2408 | 125 |
| 520 | 1. $\frac{9}{16}$ | 2800 | 136 |
| 570 | 1. $\frac{5}{8}$ | 3360 | 144 |
| 620 | 1. $\frac{11}{16}$ | 3920 | 152 |
| 680 | 1. $\frac{3}{4}$ | 4200 | 161 |
| 740 | 1. $\frac{13}{16}$ | 4480 | 172 |
| 820 | 1. $\frac{7}{8}$ | 5600 | 184 |
| 900 | 1. $\frac{15}{16}$ | 6720 | 196 |
| 1000 | 2. | 7168 | 208 |

N. B. In all the vessels of the naval service, from 74's to sloops of the 3d class, four anchors (two bowers and two sheets) are allowed, varying from 10,500 to 2,800 lbs. each, according to the vessel for which they are required.

## KEDGES.

These are considered indispensable requisites in men-of-war, and a glance at the "Outfit Tables" enables us to state the number allowed to each class of vessels in the naval service.

| Class. | No. | Weight. |
|---|---|---|
| 74's, . . | 5 | 1200 to 500 |
| Frigates, | 4 | 900 to 400 |
| Sloops, . | 3 | 600 to 300 |

NOTE. In addition to these, the same number of *boat* anchors is allowed to each vessel, together with two grapnells.

In the equipment of merchant vessels, on the contrary, kedges are a species of "scarce article." This circumstance, of course, places one in a sort of *non-plus* condition with reference to a statement of allowances. The following method of

"puddening" is that usually practised in the navy. For the *number* of *ends*, and the *size* of stuff necessary, measure the exact *thickness* of the ring, when ready for puddening, (i. e. when parcelled and woolded over,) and count the strands.* The "ends" are then cut in length, *three* times the *diameter* of the ring. Put a couple or three thicknesses of well-tarred canvas around the ring, and marl them on well—then with a strand of rope well opened, woold them over. Secure the ends to the middle point of the ring with a temporary seizing, and heave them well taut with a tail and heaver *against* the lay of the rope, on one side, and then the other, alternately, two or three times—having a hand to work them around, and to clap on temporary seizings at each heave, until the puddening is as taut as possible. Finally, put on temporary snaked seizings at the quarters and ends of the puddening, which latter should be cut square, and fagged well out. The kedges are then stowed in the main and mizen chains, where they are lashed to the lower dead-eyes of the rigging, *inside*.

Note.—Where it becomes necessary to anchor among rocks, and there is danger of losing the kedge, the following simple precaution will often be found advantageous: In lieu of bending the hawser to the ring in the usual way, take it around the *crown* with a *buoy-rope bend*, and *stop* it to the ring with a rope-yarn seizing. If now the kedge should get foul, rouse on the hawser, which will part the seizing, and bring the kedge up *crown* first. So long as the boat rides head to wind or tide, the hawser will lead in the direction of the shank, and the effect will be the same as if it were bent to the ring. If, on the contrary, there is no wind or tide, there will be no strain to part the stop, and the result will be identical.

## HAWSERS.

While treating of "Ground Tackling," it seems not out of place to refer to the subject of hawsers; more, however, with the view to introduce one or two simple points in seamanship, than to swell the work with "Tables of Allowance"—which "may be seen at all hours" in the Equipment Circulars of the Naval Bureaux.

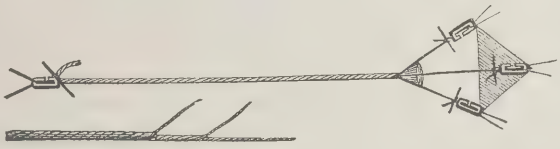
To Crown a Hawser.—The following rule will be found quite practicable in the performance of this operation: Put a stout whipping on the hawser, a sufficient distance from the end to allow for crowning. Unlay the strands to the whipping, and lay the three *inside* or heart strands up together. Then form the crown with the three *outside* ones, taking them above, and covering the remaining three, which, with the heart strands, should be whipped, and cut off even. Lastly, worm the ends of the crowning strands back into the lay of the hawser, and clap stout smooth seizings close up to the crown, and at the extremity of the worming.

To Splice a Hawser, or Shroud.—At sea, and in the absence of a proper rope-walk, this is often necessary: Unlay the rope sufficient to form the splice, and cut the strands of unequal lengths, (as represented in the following figure,) in order to prevent the splices from coming together when laid up. Take three strands of the

* In any case the rule is invariable; for if the rope used is large, the strands and consequently the number of "ends" will be less; and vice versa.

same-sized rope, (of the requisite length,) and "long-splice" them separately into the strands of the hawser, or shroud. Then secure three large snatch-blocks* at some convenient place, equidistant from each other, and to form a triangle; seizing the strands to the hooks, to which also heavers are lashed, as illustrated below. Have a large block of the same nature, with a heaver attached, secured to the extremity of the shroud in like manner, and bring the whole taut by means of ropes rove through the sheeves of the blocks—observing that the strands bear an equal strain. Put in a ropemaker's *top*, (having a hand to keep it in its place;) man the heavers, and heave round steadily, and on all the strands alike, in a direction *contrary* to the lay of the rope, which is formed at the same time, by turning the heaver on the shroud in the *opposite* way. When sufficient has been laid up, whip the end *abaft* the "top" before taking it out—remove the blocks, &c., &c. This is called a "ropemaker's splice."

Fig. 29.



Note.—Instead of long-splicing the strands together, the yarns are often singled and *knotted*.

## MESSENGERS.

These are now confined exclusively to the naval service, having long since disappeared from merchant vessels, on account of the introduction of the windlass, to which the cable is immediately brought in heaving up. In the fitting, various methods are practised—the opinions as to whether a toggle or lashing is best, being divided among the "sages" of the profession, although all agree as to the kind of rope required, viz., *hawser-laid*, which (by being of a closer lay) is better calculated to resist the action of moisture, and to make the nippers hold on. In cutting the messenger, allow three times the distance from the after part of the capstan to the manger-board, which will afford sufficient for the eyes and turns, of which latter there are *three*. The method of a toggle, though possessing many advantages in point of expedition in shifting and dipping, is nevertheless ill adapted to heaving up, on account of causing the turns to ride, and injuring the welts of the capstan. Under these circumstances, a preference may be said to exist in favor of the lashing. This is passed on *both* ends through the eyes, (which are about two fathoms apart, and short-spliced,) figure of-eight fashion, and seized with a rope-yarn stop to each other temporarily. A reference to the Rigging Tables of the naval service, gives us the following estimate sizes—there being *two* allowed to each vessel:

| | | |
|---|---|---|
| For 74's, | 15 to 14 | inch. |
| " Frigates, | 13 to 12 | " |
| " Sloops, | 11 to 10 | " |

* The object in using *snatch*-blocks, is on account of the advantages they afford by having a *swivelled* hook.

In passing the messenger, three turns (one above the other) are taken around the welts of the capstan, *with the sun*, if for the *starboard* cable, and *vice versa*—observing that the *under* part is that by which the cable is brought in: Then pass the end forward on the opposite side of the capstan, and lash the eye to that in the other, which is led under the bowsprit, and before the manger-roller. After weighing one anchor, and in order to use the messenger for the other cable, it becomes necessary to "dip." This is effected by simply casting off the lashing, and passing the end of the *upper* part *down*, or that of the *lower* one *up* through the turns (which should be slacked for the purpose) around the capstan. Finally, render the parts taut around the welts, and lash the eyes afresh.

## NIPPERS.

These are an essential accompaniment to the messenger, and are usually formed of yarns, which are marled together after the manner of a selvagee—having a whipping at each end, and about four and a half fathoms in length. In weighing the anchor, the nippers are successively applied, by first taking a round-turn around the cable, and a round-turn around the messenger, worming the ends into each respectively, and working in all cases from *forward, aft.** In addition to these, selvagees and heavers are hove taut over both messenger and cable, particularly where the latter comes in muddy, and the heave is heavy; and often under these circumstances a bucket of coarse beach-sand is found serviceable in helping the nippers to "bite."

## BUOYS.

The use of these articles is confined mostly to the naval service, since the generality of merchantmen are more frequently moored to wharves and docks, than anchored in the stream. Under these circumstances, the latter are ridded of the care which the ordinary buoy naturally requires; and in the event of needing a mark to "betray where the anchor is hidden," a spare dock-fender of white pine, having a hole in one end for the rope, is made to serve the purpose. In men-of-war, the common *nut-buoy* (which derives its name from the close resemblance it bears to a pecann-nut) is in most general use. Of late, many improvements have been made in this—and we may enumerate in particular, that of making it of *sheet-iron*, which, in addition to saving the amount of labor and gear incident to the old-fashioned slings,† has the advantage of *stopping its own leaks*, by the creation of *rust*, which arises from a constant exposure of the iron to the corrosive action of salt water. In this age of *gutta percha*, however, even this plan might be modified, (for stowage and economy at least,) by having the buoy made of *India-rubber*, and protected from chafe by a netting of rope. In cases of shipwreck, it might also be employed

* The effect of this method is, to preclude the possibility of the turns coming together and jambing, which manifestly can never take place, since each end of the nipper is drawn in contrary directions by the cable and messenger—while *both* ends are clear for taking off.

† These are cut in length *nine* times that of the buoy, which allows sufficient for the straps and slings. These, in the fitting, should be well stretched, and protected by worming and service.

as a *life-preserver*. The *size* of the buoy-rope is usually about *one-third* that of the cable; or, since this rule applies more particularly to hemp-cables, of strength sufficient to weigh the anchor by itself, in the event of its being necessary. The *length*, of course, depends upon the depth of water. In ordinary cases this is attached to the crown by what is technically termed a buoy-rope bend, which is formed by taking a half-hitch over each arm, and stopping the end along the shank. Many suggestions have been made by nautical writers, to avoid the use of the buoy-rope here described, which becomes, on account of its size, a troublesome and unwieldy fixture. As yet, however, none have been found to fulfil the desired end; and that recommended by Lieut. Totten, in his *Naval Text-Book*, has the greatest of all objections, viz. *impracticability*. This arises from the parts of the small rope (rove through the strap on the crown) becoming *hawser-laid*, and precluding the possibility of reeving or unreeving, for the passage of the "stout rope of the required size," which that author suggests, "to avoid the inconvenience" of "ordinary cases."

## STOPPERS.

These are used for many purposes, but most generally for that of securing the cables in the tiers and on deck; and as such, distinguished by names as various as their uses. Improvements, however, (as in the other branches of the profession,) have been made in stoppers, and those used at the bitts (in the *naval* service at least) are now almost universally fitted of chain, with a devil's-claw, large enough to receive one of the links of the cable, over which it is placed, and retained by a small iron-pin, running through both parts of the claw. In the other extremity a slip-hook and ring is attached, by which it is secured to the stopper-bolts of the deck. Its length is about four feet and a half, and in size depends upon the class of vessel for which it is required. This is designed to supersede the ordinary *deck-stopper*, which is usually fitted with a double-wall and crown-knot in one end, and in the other a hook and thimble, securing it to the ring-bolts in the deck. This, which is formed of hawser-laid rope, about a fathom and a half long, is applied to the cable either before or abaft the bitts (as may be necessary) by means of a lanyard passed around both cable and stopper, (from *forward, aft,*) usually in six turns, and the end, which is brought up between both, wormed forward, and seized to the former. With a *hemp*-cable, the lanyard is passed *against* the sun, and wormed into the lay.

The universal adoption of the windlass in merchantmen, (to which we have already had occasion to refer,) necessarily obviates many of these appendages, which are regarded in the navy as essential requisites. In lieu of the stopper described above, a simple *bitt-stopper* is employed to nip the cable on the bight forward of all. This usually consists of four or five fathoms of rope, tailed out like a nipper at one end, and fitted with a clinch knot in the other, by which it is secured through a hole in the foremost samson-knee.* These, with the exception of *belaying*-stoppers, (which are so simple as to render a description unnecessary,) are about all that con-

* In merchantmen, stoppers *abaft* the bitts are but seldom used, on account of the lockers being so near the windlass. In ordinary cases, a small deck-jigger is clapped on, and hauled taut; and in *extra*-ordinary ones, the cable is weather-bitted, i. e. by taking an additional turn around the welts of the windlass.

cern the merchant service. In the navy, on the contrary, hatch and tier stoppers are in frequent use—although the lately-invented *compressor** is found to obviate greatly the old and almost numberless phalanx of "cable-gear," which even now lingers as a vestige of vanished days.

Note.—On board of the "Cumberland," in coming to anchor, it was always the practice to let the anchors take the chains from the lockers—using the compressors to stopper when required. This plan invariably succeeded, and saved a great deal of trouble. In mooring, the *lee* cable (for veering) was unbitted.

## LOG-LINE AND GLASS.

To attempt an enumeration of the disasters which have resulted from the neglect and imperfection of this simple instrument, would occupy more space than the already prescribed limits of the work will allow. Yet the repetition of a few recognised principles seems not inappropriate, while referring to the equipment of the log-line and glass. The late Captain Glascock, who lays more stress than is usually bestowed upon the subject by nautical writers, aptly expresses himself thus: "The 'dead reckoning' is seldom unchecked by other data, and people who perform long voyages, and trust to astronomical observations, pay but little regard to the 'run' given by the log. The naval astronomer, with his chronometer, sextant, and 'Nautical Almanac,' and with the sun, moon, and stars unobscured, feels for a time independent of the log; but of what avail is astronomical knowledge, if, towards the termination of a passage, when pushing for a port, the heavenly bodies become invisible to the human eye? This is a circumstance by no means unusual in temperate climates for days and nights together, particularly on approaching the *land*. At periods like these, even the astronomical navigator must lay aside the watch and sextant for the ruder instruments of the lead and log. Let him therefore bear in mind that an incorrect return of the ship's periodical 'run' may be the sole and immediate cause of her total loss." With regard to the merchant service, these observations seem directly suited, although it is by no means intended to place the practice of navigation in the navy beyond the pale of their application to it also. For though the commanding officer himself, and the master (under whose particular province the log-line and glass fall) may inspect their adjustments as frequently as may be essential to their correctness, yet the carelessness of those who *heave the log*, more than counterbalances the errors which would result from an *incorrect log*, *properly* hove.

In the fitting, an observance of the following points will be found to render the log sufficiently accurate for practical purposes. *Wet* the line, which should be well stretched, before cutting, and allow half the length of the ship's keel, for the "stray," which point, mark with a white rag. Then "divide the knots into portions of forty-seven feet three inches, to the twenty-eight-second glass,"—and mark this distance (correctly measured) with brass or copper tacks in one of the *midship* deck-planks, for future reference; observing every third inspection of the line, which should be

* This (of which in the Cumberland there were two to each bower, one on the berth-deck, and the other in the hold) consists of an iron elbow, bolted in one end to the under side of the beam just forward of the chain-pipe. The other has usually a small luff-tackle attached, which is used to nip the compressor taut around the chain.

done once a week, to shift it end for end. The reel, in order to turn with ease, were best, if fitted with friction rollers—having the cheeks about six inches in diameter, and separated by a space of about eighteen inches. In *timing* the glass, (which should be kept in some convenient place free from the influence of *moisture*,) instead of using an ordinary watch, refer to the second-hand of the chronometer.

In *heaving the log*, (which is quite as important as any feature in the equipment,) a portion of the "stray," sufficient to carry the chip clear of the eddy formed by the wake, should be carefully *flaked* (*not coiled*) in the hand, and thrown over the *stern*—the person so doing standing on the lee side abaft, observing that the sails are full, and the ship either "by" or at her course, and directing the assistant to hold the reel well up, careful that no impediment is offered to the free progress of the line. When the first point of reckoning, or the mark of the stray, passes through the officer's hand, he gives the order, "*Turn!*" which the glass-holder repeats, "inverting the glass by a timely turn of the wrist," and watching the moment the last grains of sand fall through, he cries "*Stop!*" The line being immediately stopped, the mark nearest the officer's hand shows the number taken from the reel —estimated in fathoms, which, together with the knots, shows the distance run by the ship in the elapsed time. A calculation of the *average* velocity, with an allowance for the heave of the sea, the steadiness of the wind, and the manner of steering, (during the interval of the previous cast of the log,) is then made by the *watch officer*, and inserted opposite the course. These are all points of the utmost importance, and should have a due share of consideration, as affecting materially the position, progress, and safety of the ship. If it be true in morals, that "charity hideth a multitude of sins," it is not less certain in the nautical code, that correct navigation is the *only* plaster for *bad* seamanship.

## LEAD-LINES.

In tracing the various improvements which have been made from time to time in the nautical profession, it is not a little strange that the lead-*line* has been permitted to remain thus long in *statu quo*, with the same rude marks which it probably had in the offset of its use. Yet such is the fact, notwithstanding the number and abilities of professional writers, who have, one by one, handed down, with the care of a scriptural translation, these relics of primitive seamanship.

Some years ago, a "deep sea" lead was invented, which sought to remedy the evils of continual error, and the inconvenience resulting from the *antique* system of marking still practised. This consisted of an instrument of cylindrical shape, containing a small glass tube, having a hole in the lower extremity, protected by a delicate spring, which (acted upon by the upward pressure of the water) permitted a quantity, proportioned to the depth, to rise in the tube as the instrument descended below the surface, which distance was duly indicated by means of a graduated side scale. This contrivance, however, far from succeeded in answering the conditions sought for by its ingenious inventor, on account of the delicacy of the spring, and the corrosive influences of the element to which it was exposed. Under these circumstances, we are forced back to first principles, and obliged to retain the marks on the line, in order to correct the very errors which the instrument was designed to avoid.

With due deference to the *age* of the present method, the following system is offered as one, at least, which has the advantage of revealing the "marks and deeps" without regard to the "*ocular* demonstration" of the existing order.

The *hand lead-line* (which is seldom over thirty fathoms in length) may be marked thus:

| | |
|---|---|
| At 2 fathoms | 2 beads.* |
| " 3 " | 3 " |
| " 5 " | leather. |
| " 7 " | 1 knot. |
| " 10 " | 1 bead. |
| " 13 " | 2 knots. |
| " 15 " | rag. |
| " 20 " | toggle. |
| " 25 " | 2 beads. |
| " 30 " | 3 " |
| " 35 " | short splice. |

In this system no two marks are the same, except those at 2 and 25, and at 3 and 30, which, from their distance apart, never can be mistaken for one another. From an examination of the old rule, we perceive, on the contrary, that 3 and 13, 5 and 15, 7 and 17, and 25 and 35, are identical; and moreover, consist of *white* and *red* rags, as if *these* were distinguishable colors in the *dark!*

Again, the marks on the line of the *deep-sea* lead may be modified for the better by an adoption similar to the following:

| | |
|---|---|
| At 15 fathoms† | 1 bead. |
| " 20 " | 2 " |
| " 30 " | 3 " |
| " 40 " | 1 knot. |
| " 50 " | 2 " |
| " 60 " | 3 " |
| " 70 " | rag. |
| " 80 " | leather. |
| " 90 " | splice. |
| " 100 " | toggle. |

The advantage of this system is, that no two marks are the same, which is far from being the case with the deep-sea line now in use.

In order, however, that the reader may compare the old system of marking with that suggested in the preceding paragraph, the following extract is added from Totten's "*Naval Text-Book.*"

* These consist of small broad flat rings of *lignum-vitæ* secured to the line by a wooden pin in each, running through and through—the beads being separated from each other by a space of two or three inches.

† The length of this line, and its application to great depths, renders a mark before 15 unnecessary.

"Both the hand and deep-sea lines are marked as follows:

| | | | | | |
|---|---|---|---|---|---|
| At | 2 | fathoms | from | the | lead, with 2 strips of leather. |
| " | 3 | " | " | " | " with 3 strips of leather. |
| " | 5 | " | " | " | " with a white rag. |
| " | 7 | " | " | " | " with a red rag. |
| " | 10 | " | " | " | " with leather, having a hole in it. |
| " | 13 | " | " | " | " as at 3. |
| " | 15 | " | " | " | " as at 5. |
| " | 17 | " | " | " | " as at 7. |
| " | 20 | " | " | " | " with two knots. |
| " | 25 | " | " | " | " with one knot. |
| " | 30 | " | " | " | " with three knots. |
| " | 35 | " | " | " | " with one knot. |
| " | 40 | " | " | " | " with four knots. And so on. |

"In marking the deep-sea line, the first marks before twenty fathoms may be omitted, with the exception of the ten-fathom mark, and if you please, the fifteen, as directed above."

NOTE.—While fitting the lead-lines the *breast-bands* should not be omitted. These are best if made of white cotton canvas, about a fathom in length, three inches wide, and tapering at each end, with eyelets, into which laniards are spliced.

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Such articles as chain-hooks, hook-ropes, clear hawse-pendants, &c., are so subordinate in their reference to Ground Tackling, and so simple in their construction, that it seems scarcely necessary to swell the subject beyond its present limits with their description; and we turn at once to the concluding article of Part I.

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## GUNS.

In this article it is designed only to include such portions of the subject as fall directly within the pale and province of the seaman—leaving the *gunner* to ponder and puzzle, to his heart's content, over the *Theories* and "*Windage*" of *Hutton, Beauchant, Douglass, Mordecai, Ward,* and the host of "ball-proof" authorities.

The following method of getting in the guns (which embodies the routine practised on board of the "Delaware," 74, at Leghorn) is gathered from the notes of an able and experienced officer of the navy.

Having the guns brought alongside in scows or lighters, brace and secure the *main*-yard, and prepare to get them on board thus:* Lash a large single block on the starboard yard-arm, (if that be the side used,) far enough out to allow the pur-

* By a reference to the subject of sheet-anchors, on page 79, it will be perceived that the purchases employed are nearly identical with this.

chase depending from it to hang just clear of the ship's side. Up through this block and another at the lower cap, reeve the pointed end of one of the top-pendants, leading it from thence to the deck. Hook the top-tackle into the thimble of the latter, so that the fall shall lead from the *lower* block, and round up on the pendant, until the *upper* block is some two or three feet from the yard; then secure the pendant at the bitts, and attach a block to the yard as a leader for the hauling-part of the tackle, which should also be led through another block at the cap and to the deck. Now set well up the opposite topmast breast-backstays, and the topsail halliards, racking the tye aloft. Hook both top-burtons (overhauled from the mast-head) to straps on the yard-arm—one inside and one outside of the gun-purchase; as also, a burton from a strap around the mast, (in the wake of the yard,) to act as a rolling-tackle, and relieve, in part, the strain on the opposite lift and truss. Brace the yard so that it will be directly over the port, through which it is intended to take the guns—haul taut the trusses* and rolling-tackles, and bring an equal strain on the burtons, lift, and topsail-sheet, (which latter should be clinched over the lower cap;) then pass a stout lashing of inch rope around the mast and yard, (between which a mat should be placed,) observing that the under and lower turns are passed in such a manner as to share equally in the strain and pressure.

Have a pair of slings fitted of breeching-stuff to go over the *pomillion* with an eye, which is formed at one bight by a stout seizing, and lay both parts along on top of the gun, securing them by a lashing just forward of the trunnions—the bight being left clear to act as an eye, into which hook the lower block of the yard-purchase. In all ships-of-war there should be bolts screwed into the carlines above the breeches of two or three of the guns on each side of the deck, to facilitate the operations of dismounting, shifting, &c. To one of these at the port, at which the guns are taken in, lash a block with a short strap, having a pendant two or three fathoms in length, fitted with a hook in one extremity, and an eye in the other rove through it, and hooked to a thwartship-tackle leading across the deck. Now secure the port from chafe, by lining it with thin boards, (particularly on the upper and outer edges,) and have the carriages in readiness—viz. with the quoins in, and the cap squares thrown back. Lash the slings on to one of the guns, and bend a hawser to the eye of the latter, of length and strength sufficient to reach the bottom, and weigh the gun in case of accident. Hook on the yard-purchase to the centre of the slings and the pendant, from the port to the pomillion,† and sway away, dropping the scow from underneath. When the breech of the gun is as high as the lower sill of the port, rouse in on the pendant, and run the carriage under, lowering away of all. Cast off the slings—transport the gun to its proper port, and get the others on board in the same manner, running them out square, fitting the gear, and securing them as follows: Let the breech come down by hauling out the quoin and render the breeching taut through the pomillion—turning the bight over, *with the sun*, and passing a stop through it and the side-shackle, above which, hook the side-tackles to eye-bolts, and haul them well taut, taking two half-hitches with the

* Where the patent iron truss is used, it should be unkeyed, in order to let the yard rest against the mast.

† In case the pomillions are cut or fitted with a shark's-mouth, in order to permit the breechings to be shifted without the trouble of unreeving, as is now the case, the lower deck-pendant may be hooked to the slings themselves, as the weight of the gun will prevent the possibility of their being forced off.

running-part over the last step of the carriage. Hook the double block of the train-tackle *abaft*, (if on the port side, otherwise vice versa,) and the single one forward, hauling it taut; then bring all parts close together around the pomillion, and rack the end. Finally, expend the balance of the side-tackle falls around the breeching* and train-tackles on each side, (between the trucks,) in frapping-turns—heave the gun up—put in the quoin, &c.

This method of getting in the guns, from the rapidity with which it can be carried into execution, is preferable to having a garnet, (rove through a hole in the deck, in a line with the mast-head,) as commonly practised.

NOTE.—The slings for *carronades* consist of two double straps with eyes, (formed by stout seizings,) large enough to go over the pomillion and muzzle toggle respectively. The strap of the former (which is fitted with a thimble for the yard-purchase) is then thrust through that of the muzzle, as represented by the following figure, and bound down to the gun by a stout lashing just forward of the centre.

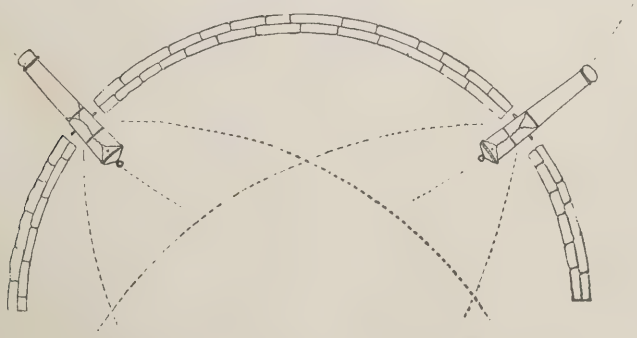
Fig. 30.

The lower-deck guns and carronades may be got in at the same time, if need be, using the *fore*-yard for the latter, and the pendant-tackle as a stay-purchase to bring them over the rail.

## BURSTING GUNS.

Though perhaps foreign to the purpose of a work, designing to treat only of the subject of seamanship, the following notes taken during one of the Naval Expeditions in the Gulf of Mexico may serve a useful purpose, by preventing at least *one* of the thousand accidents to which sailors are exposed in the dangerous service of bursting guns.

Fig. 31.



* With the many improvements which have marked the science of naval gunnery within the last few years, breechings have not escaped attention; and they are now fitted with shackles and thimbles—a plan which renders "shifting" a momentary operation.

During the summer of 1847 the bomb brig "Stromboli," stationed in the Guazacoalcos river, was detailed by Commodore Perry to destroy a small battery on the right bank; and on bursting the guns contained in the fort, it was universally remarked that whether fired from the muzzle or vent, (some having been spiked prior to abandonment by the Mexicans,) the explosion occurred precisely in the same manner. And even to the position of the fractures—the number of pieces and the direction in which they were thrown—the same invariable rule was observed throughout. The preceding simple diagram will however better explain.

The pieces are indicated by the fractured line, and their course by the dotted curve, which, as we perceive, forms an angle varying from 10° to 15°, with the axis of the bore. In one or two instances the pieces in the vicinity of the charge were thrown with a very high velocity (in the rear of the gun) to the distance of nearly an eighth of a mile, inscribing an elliptical curve in the air, with a transverse radius of about thirty feet; while the breech and muzzle parts were impelled to the comparatively limited distance of fifteen or twenty feet only. The long eighteens, of which there were three, required thirty pounds of coarse cannon powder to explode them; while with the twelves, (five in number,) nineteen and twenty pounds were found sufficient, although the thickness of metal in both calibres did not materially differ.

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In concluding this portion of the work with the foregoing note, it is not without a degree of modesty and deference, simply on account of its importance to the science of naval gunnery, and a remembrance of the fact, that "whoever, indeed, in treating of any subject recommends (whether on good or bad grounds) a departure from established *theory*, must expect to encounter opposition." Instead, then, of attempting to identify the phenomena (?) with existing practice and principles, I have been careful not to change the original expressions of the note, further than to admit of the introduction of date and locality. Under these circumstances, it is but a *nut* gathered by the wayside, and as such offered to the friendly hammers of the *Ordnance Corps.*

# EVOLUTIONS.

# PART II.

## EVOLUTIONS.

### INTRODUCTION.

To enter into the minute details of every nautical manœuvre would, indeed, occupy an extent far beyond the limits which this work was designed to go; and when we glance even casually over the wide range of condition and circumstance which they cover, it is manifest that a lifetime of itself would be insufficient for the proper accomplishment of a record so wide-spread and voluminous. Under these circumstances, it must suffice for our present purpose to embody simply such as are deemed of material importance to the profession of seamanship, and to the province of the tactician—for many evolutions which *might* be given are so well understood by persons who have been at sea, even for a limited period, that a repetition of them here (however much it might conduce to the *completeness* of the compilation) would only be regarded as so many imputations upon the understandings of men, to whom they are already perfectly plain and simple. For this reason, it will be my design to gather from the multiplicity before me rather a *quality* than a *quantity*, and to present some few, which, though far from having the absolute credentials of originality, are nevertheless such as have been, through many long and boisterous years of professional experience, the guiding criterions of practical men. In this view of the subject, many of the points will necessarily appear as "Notes" or "Hints," and without reference to any particular order of arrangement.

### FURLING SAILS.

The manner of executing this manœuvre depends in some measure upon the position and circumstances of the ship. If the sails, for instance, are hauled out by the *bowlines*, the labor of "short'ning" may be greatly facilitated by adopting a few precautions, which are recommended by Fordyce, and practised by naval officers generally.* He says, 'As the tacks and sheets are generally kept unrove in har-

* *Outlines of Naval Routine*, page 101.

bor, the *courses* may be hauled up by single clew-ropes, one buntline, and the leech-lines of a side; and the *topsails* by the buntlines only, led through a lizard at the clews: as the stress of the work is on the buntlines and clew-ropes, but few hands are required at the clewlines.' Again—'The hauling down of the head sails may also be rendered much easier by having the halliards racked, and coiled at the mast-head, and a hand there ready to cut the racking when the word is given to shorten sail.'

The routine of duty and the orders are then as follows:

"*All hands shorten and furl sails.*" Man the clew-ropes, buntlines, leech-lines, down-hauls, and brails, having the bunt-ropes and jiggers overhauled, and ready for hooking to the gluts, and hands by the halliards, out-hauls, and bowlines, to let them go.

"*Aloft, topmen!*" and allow them time to reach the futtock-rigging.

"*Aloft, lower-yardmen!*"

"*Haul taut—clew up—haul down—lie out and furl.*"

Gather up the slack of the sails smartly, and pass the leeches, points, and bowline-bridles in taut along the yard towards the bunt—slack down the buntlines—hook the bunt-jiggers—toss up, and skin the sail taut and smoothly in the head-band—keeping the bunt square in the slings, and heaving the clews forward in the wake of the quarter-blocks—slew the head-earing cringles up fair, and pass the gaskets at right-angles with the yard—parallel with each other, and without turns.

"*Lie in—down booms—and down from aloft*"—square the heel of the booms, keeping them at equal distances apart on each side of the bunt, and parallel with the yard—secure the glut to the tye by a temporary racking—unhook the bunt-jiggers, stop the bowlines to the jackstays, on each side of the bunt, haul them taut, together with the 'jib and staysail halliards, and see that the clew-lines are close up. Then square yards; after which, haul taut reef-tackles, sheets, and all slack ropes.'*

This routine, with the exception of shortening, answers in furling where the sails are simply triced up by the buntlines as in ordinary cases. In furling the *fore-and-aft sails*, canvas covers are now almost universally used: these extend from the extremity of the gaff to the tack-cringle of the spanker and trysails, and on the jibs, the length of the foot of the sails. These are simply secured by means of nettles around the trysail-mast, or boom, and the sail brailed up, or hauled down, as snugly as possible. When covers are not used, as in the merchant service, the fore-and-aft sails are furled in the after cloths, as the seams are thus brought up and down. In furling a boom-mainsail, Fordyce suggests the following routine: 'Haul over the weather boom-sheet, and crotch the boom—taking care to have both boom-sheets hauled taut and belayed, that there may be no danger of the boom fetching way. Lower the peak and throat halliards (one or two hands keeping the sail clear of the wheel) till the gaff be low enough for the men, when standing on the boom, to reach over and hand the sail. Secure the peak thoroughly to leeward as well as to windward by several double turns of the down-haul to the boat's davits or cleats—man the boom, and hand the sail. The most important point in furling the boom-mainsail, is to have the boom and gaff so secured that there may be no danger of either fetching way when the men are up handing the sail. In hoisting or lowering the gaff, the peak ought to be kept a little higher than the throat. It will otherwise

* *Outlines of Naval Routine*, page 129.

be much more difficult to work.' It is almost needless to add, that this practice is observed on board of river and coasting vessels; with, however, the addition of spilling lines leading from the boom to the mast-head, by means of which, the gaff and sail are gathered in at once without further trouble than simply letting go the halliards. This plan was adopted in the fitting of the spanker on board the packet ship "New-World," by Captain Skiddy, and found very convenient in short'ning sail suddenly.

Note.—In furling the *topmast-staysail*, (which is *stowed* in a netting on the bowsprit,) the labor and difficulty may be sensibly diminished by bending a small line (rove through a block at the nip of the stay) on to the clew, and rousing that part of the sail forward at the time of hauling it down.

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## DEFINITION OF TIDES.

*A windward tide*, is when the wind and tide are contrary.
*A leeward tide*, is when the wind and tide are together.
*A windward ebb*, is when the tide is setting out, and the wind blowing in.
*A windward flood*, is when the tide is setting in, and the wind blowing out.
*A leeward ebb*, is when the tide and wind are both setting out.
*A leeward flood*, is when the wind and tide are both setting in.

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## TENDING SHIP.

The following "hints" on tending ship, are taken from the notes of an old English collier,* and refer especially to the duty of a pilot:

To know how to manage a ship at single anchor, is a necessary part of seamanship; but all seamen have not the same opportunity of learning this practicable branch of their duty: on this account the necessity of a particular reference to the subject is obvious, for many of the treatises hitherto have been too scientific to be useful; for while a mate is calculating the angle that the buoy makes with the ship's head, instead of *bracing the yards about*, and setting the sails necessary to *back or fill*, he will often have to heave up a foul anchor, or, what is worse, the ship may be lost in consequence of its being so.

But suppose the mate, or pilot, have ever so perfect a knowledge of their duty, they cannot always be on deck: every man therefore who is intrusted with the charge of an anchor-watch, should know when *to ease or give the ship more helm*, and in case of a shift of wind, to know how to change the yards; for if he has not sense enough to brace the after-yards about, and hoist the fore-topmast staysail up,

* The late Capt. Henry Taylor.

while the mate is turning out, she may tumble over her anchor before he can get upon deck, and without his knowing she has done so.

The instructions under the several heads are short, and sufficiently plain and easy to be understood by any one who knows the technical terms of seamanship.

## HINTS.

Riding in a tideway, with a fresh breeze of wind, the ship should have what is called a short scope, say, forty-five or fifty fathoms of cable, and always sheered to windward, *not*, however, with the helm hard down, but more or less so, according to the strength or weakness of the tide. Ships have often been known to sheer their anchors home, drive on board of other ships, and on the sands near them, before it was discovered that the anchor had been removed from the place where it was let go.

It has been thought by some theorists, that ships should be sheered to leeward of their anchors, but the common practice of the most experienced seamen is against this opinion; for it is found that when a ship rides to a leeward tide, and is sheered to windward, with the wind two or three points upon the bow, and blowing hard, in the interval between the squalls, the sheer will draw her towards the wind's eye; so that when the next squall comes, before she is pressed astream of her anchor, it is probable that there will be a lull again, and the spring which the cable got by the sheer, will greatly ease it during the squall.

Riding with the wind two or three points upon the quarter, when the wind and tide are nearly of equal strength, and when ships are so liable to break their sheer, if the helm should be a-weather, or the ship sheered to leeward, I cannot conceive how she can do otherwise than be continually breaking her sheer.

Every seaman knows that no ship without a rudder, or with the helm left loose, will veer; in such situations they always fly to: this proves that with the wind pressing upon the quarter, and the helm a-lee, a ship will be less liable to break her sheer than when the helm is a-weather. Besides, if the helm is a-lee when she breaks her sheer, it will be a-weather when the wind comes on the other quarter, as it ought to be, until she either swing to leeward, or coming to sheer the other way, bring the buoy on the lee quarter. Now if a ship break her sheer with the helm a-weather, it throws her head to the wind so suddenly, as scarcely to give time to brace the yards about, and very probably she will fall over her anchor before the fore-topmast staysail can be got up.

When the wind is a-cross, or nearly a-cross, off shore, or in the opposite direction, ships will always back: this is done by the mizen-topsail. Such as have no mizen-topsail, commonly use the main-topsail, or if it blow fresh, the yards themselves are sufficient.

In backing, a ship should always wind with a taut cable, that you may be sure the anchor is drawn round. In case there is not a sufficiency of wind for that purpose, the ship should be hove a-peak.

Riding with the wind before the beam, the yards should be braced forward; and f abaft the beam, brace them all aback.

If the wind be so far aft that the ship will not back, (which should never be attempted, if when the tide ceases, she forge ahead, and bring the buoy on the lee quarter,) she should be set ahead; if the wind be far aft, and blowing fresh, the utmost care and attention is necessary, as ships riding in this situation often break their sheer, and come to windward of their anchor again. When a ship lies in this manner, the after yards must be braced forward, and the head yards the contrary way: she will lay safe as long as the buoy can be kept on the lee quarter; or supposing the helm a-port, as long as the buoy continues on the port quarter. With the helm thus, and the wind right aft, or nearly so, the starboard, main, and fore braces should be hauled in: this supposes the main-braces to lead forward.

When a ship begins to tend to leeward, and the buoy comes on the weather quarter, the first thing to be done is to brace about the head yards; and when the wind comes near the beam, set the fore-topmast staysail, and keep it standing until it shakes; then brace all the yards sharp forward, especially if it be likely to blow strong.

It sometimes happens that when the fore-topmast staysail is set too soon, the ship's head will pay off, and she will break her sheer; to prevent this, and to keep the wind broad upon her beam, it will often be found necessary to set the spanker also, which should always be taken in as soon as the wind comes before the beam, otherwise the ship's head will be thrown in the wind too soon.

If laying in the aforesaid position, and the ship break her sheer, brace about the main-yard immediately: if she recover and bring the buoy on the lee or port quarter, let the after yards be again braced about; but if she comes to a sheer the other way, by bringing the buoy on the other quarter, change the helm, and brace to the head yards.

Riding to a leeward tide with more cable than a short scope, and expecting the ship will go to windward of her anchor, begin, as soon as the tide ceases, to sherten in the cable. This is often hard work, but it is necessary to be done, otherwise the anchor may be fouled by the great length of cable the ship has to draw round; but even if this could be done without fouling the anchor, the cable would damage the bows or cutwater.

When the ship tends to windward, and must be set ahead, hoist the fore-topmast staysail as soon as it will stand,* and when the buoy comes on the quarter, haul down the fore-topmast staysail, brace too the head yards, and put the helm a-lee; for till then the helm must be kept a-weather, and all the yards full.

When a ship rides to a leeward tide, and the wind increases, care should be taken to give her more cable in time, otherwise the anchor may start, and she may not easily be brought up again, and this care is the more necessary when she rides in the hawse of any ship. Previously to giving a long scope, it is usual to take a weather-bitt; that is, a turn of the cable over the windlass-end, that in veering away, the ship may not overpower you.

If the gale continue to increase, the topmasts should be timely struck, but the fore-yard should seldom, if ever, be lowered down, that in case of parting, the foresail may always be ready.

* In moderate weather the jib may also be set.

In a tideway a second anchor should never be let go, but when absolutely necessary. A ship will sometimes ride easier and more securely (especially if the sea run high) with a very long scope of cable, and one anchor, than with less length and two anchors; however, it is advisable, as a preventive, when ships have not room to drive, and the night is dark, to let fall a second anchor under foot, with a range of cable along the deck. If this be not thought necessary, the deep-sea lead should be thrown overboard, and the line frequently handled by the watch, that they may be assured she rides securely.

Prudent masters seldom lay a week in a roadstead without heaving their anchor in sight, even though they have not the least suspicion of its being foul. There are other reasons why the anchor should be looked at: sometimes the cable is fouled by sweeping wrecks, or anchors that have been lost, or from rocks or stones; and it is often necessary to trip the anchor in order to take a clear berth, which should be done as often as any ship brings up too near. As little time as possible then should be lost in securing a clear berth, for while neglecting to do so, the wind may increase, and prevent the shifting of the ship's situation, and the most fatal consequences may follow from riding too near other ships; for one ship badly situated with respect to others, with bad ground tackling, and worse management, may be the means of driving twenty sail adrift on the strand, or sands near them.

A good roadstead is better and safer than a bad harbor: therefore never leave the former for the latter, but in cases of real necessity; and there is but one case where it can be necessary, and that is, when you can ride no longer, and have no lee-road to fly to for refuge.

No ladened ship, however strongly or fully built, can lay aground, without receiving damage, and probably a great deal more than at first discovers itself. Sharp-built ships, in such situations, often break all their bottom-timbers: this they may do and yet swim, but coming to work at sea, the hidden wounds often break out, and inevitable ruin follows. Some of them, however, fortunately for their crews, receive so much damage as to be condemned in harbor.

The trouble of frequently looking at the anchor, or changing a roadstead, should never be an object of consideration; but rather consider, that on so doing may depend the safety of the ship and cargo, and even of life.

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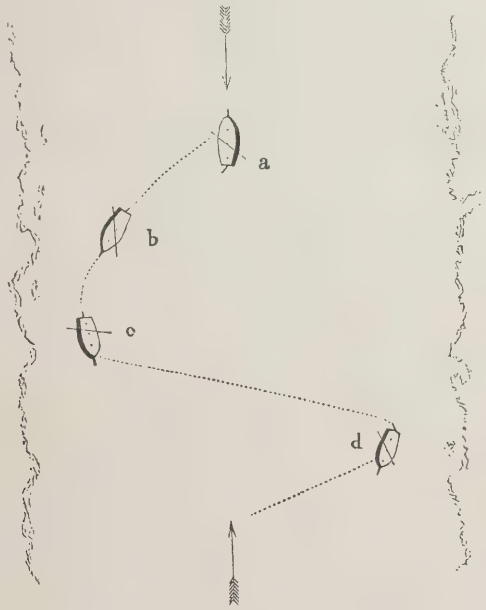
## BACKING AND FILLING IN A TIDEWAY.

It is a fundamental truth in seamanship, that a vessel is always under command of the helm with the main-topsail on her; which arises from its central position, and the extent of sail-surface (proportioned in all cases to her size and capacity) exposed to the action of the wind. This, in connection with the spanker and jib, will, under all the circumstances peculiar to "backing and filling," render a ship easy of management. Assuming, then, these premises to be correct, a brief explanation of the diagram will be sufficient to make every thing in reference to this evolution perfectly

understood. Suppose the ship, as in (*a*,) to be riding by the starboard cable, head to tide, with the wind aft; since if it were otherwise there would be no necessity whatever for the evolution. Heave into a short scope, loose the *main-topsail*, *spanker*, and *jib*—set the two former, and brace the main-yard up by the starboard braces—man the capstan, and heave again: as the anchor breaks ground, put the helm *down*, or to starboard. The wind now acting on the after sails, in conjunction

Fig. 1.




with the helm and tide, (operating on the lee bow,) will bring the ship to the wind, when the helm must be righted, the jib hoisted, and the sheet trimmed aft. In this position she will shoot over to the starboard shore, at the same time being carried down by the tide, as represented by (*b*.) When it becomes necessary to head the other way, down *helm* and *jib*, and as the topsail shakes, check the lee braces, and let it come nearly square *aback*. The position of the ship will now be that denoted by (*c*,) and the resultant of the two forces of wind and tide, from the conditions of the evolution, will be a diagonal line approaching to the required course of the ship, in a ratio proportioned to the power of the tide over that of the wind; while any tendency to fall off or come to, on account of the former, can always be controlled by means of the helm, spanker, and jib. When she reaches the opposite shore, *up helm*, *jib*, and *main-yard*, and bring her to the wind on the port tack, as in (*d*,) which will be precisely the same position she had after casting from her anchor. It will be observed that the evolution is executed by *backing* on one tack and *filling* on the other, which is essentially "backing and filling." This method, from its simplicity and feasibility, is eminently preferable to the old one under three topsails, which can scarcely be called either the one thing or the other, since the manœuvre is only resorted to in narrow channels, where the ordinary conditions of tacking and wearing are precluded.

## RULES FOR SAILING.

Ships steering or sailing with a fair wind, are always to give way to those which may be *close-hauled:* if with daylight, a clear night, and clear weather, the former should run foul of the latter, the master is wholly to blame; and the fault is aggravated, if during the night he has such forward sails set as to prevent seeing objects ahead. It will be no excuse to say that seamen were stationed on the forecastle, for the purpose of looking out; because sailors are too generally careless, and often fall asleep. It is always safest to go under the stern of close-hauled ships when near them.

Ships sailing different ways with the wind on the beam, are equally in fault if they run foul of each other. If one be light and the other laded, a greater share of blame should lay on the master of the light ship, because such ships will answer their weather helm very quickly, but few laded ships will do so.

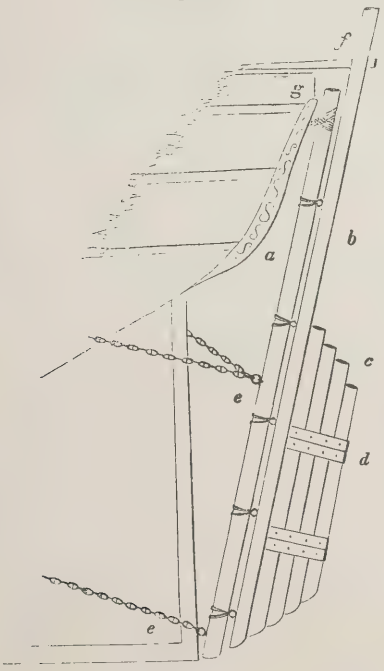
If two ships beating to windward to the same point or place, where they have sea-room, and fairly under way, (providing the weather be clear, or so clear that they may see each other at a cable's length distance,) run foul of each other, they are, in all probability, equally to blame; but if one of them on such an occasion, when quick exertion is necessary, put his helm up, and the other throw his ship immediately in stays, the first would be blameable and not the last, because it is well known that few (especially laded ships) will *quickly* answer their weather helm. Some ships will bear off till they bring the wind abaft the beam, and run with it to a considerable distance; and as, by running so far from the wind, their velocity will be greatly increased, the greater will be the danger of sinking one or both if they meet. The most prudent method in this case is, for both ships to put their helms hard down, and then if they should fall alongside of each other, they will touch gently, and probably do no damage. There are few seamen but know this ought to be done, but they often, and too often fatally, are induced to try the experiment of wearing, to avoid the trouble of staying their ships; besides, men ought to be deterred from attempting to wear when they suddenly meet with a ship at a small distance from them, from the consideration that both ships may do the same, and then if they meet, the crash is dreadful indeed.

In turning up rivers much damage is often done; and more through want of care than want of knowledge. The edge of the tide is the rule for putting about, even though the tide does not run half the breadth of the reach. Some imprudently stand *out* of the tide, and occasion thereby much trouble to themselves, and many of the skips in company with them; for when they come out of the eddy, and the edge of the tide takes their lee bow, it throws them in the wind, and though the helm be hard up, the spanker-sheet a-flow, or the peak of the mainsail down, she will drive, without command, probably the whole length of the reach. Let all others be careful not to stand too near her, for if damage be done, they must answer the consequences.

## SKIDDY'S RUDDER.

The following simple and easy plan of constructing a temporary rudder at sea, by Capt. Wm. Skiddy of New York, is submitted as a substitute for the more expensive and difficult one commonly known as *Packenham's Rudder*. The materials of which this rudder is made, can always be readily obtained on board of any merchant vessel.

Fig. 2.




*a*, False sternpost—Topsail or cross-jack yard, or indeed any spar about that size.
*b*, Main rudder-piece—Mizen-topmast, or jib-boom.
*c*, Spare spars cut to form the rudder
*d*, Plank nailed on.
*e*, Ring-bolts from the sides, or decks—having large *eye*-bolts for the guys.
*f*, Tiller shipped in the fid-hole, and to steer as usual.
*g*, False post lashed to the taffrail.
Ring-bolts from the sides, or deck, to form the jury pintals, the bolts being drove into the rudder-stock or topmast, and the rings lashed to the false post.

If *ring*-bolts cannot be procured, *eye*-bolts may be substituted by driving some into the rudder-stock, and some into the post, and running spare bolts, or jack-rods, from the yards, through them thus:

Having thus completed it on deck, shackle on the chain-guys, as illustrated in the figure, observing to keckle them with strands of old rope, to prevent injury to

the copper, and stop them up and down the false sternpost with rope-yarns. Then lower the rudder over the side—hoist it up abaft by means of a tackle, and secure it with *cross*-lashings to the central point of the taffrail, cutting loose, and passing the chain-guys forward on each side respectively, when they should be hove taut, taking care that the heel is hauled in securely to the sternpost of the ship. Finally, lash a block on each side of the tiller, reeve the wheel-ropes, and steer as usual.

Note.—Forty-five degrees is the most advantageous position for a ship's rudder to act; but as the water strikes the rudder in proportion to the *run* of the ship, so the tiller will have a less angle with the keel; for supposing the spread of the run to be 20°, the half, or 10°, will be the angle which the water makes with the keel when thrown out of its direction towards the bow; therefore the rudder to be struck at a mean by the water with an angle of 45°, the tiller must move over to an angle of 35°.

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## WEIGHING FROM AMONG ROCKS.

On the evening of the 16th of December, 1812, the "Magnificent," of seventy-four guns, being one of a squadron under the orders of Rear-Admiral Sir Philip Durham, was by that officer directed to take up a position, and anchor between Chasseron and Isle of Rhe, in the neighborhood of "Basque Roads." Previously to furling the sails, the sky being dark and cloudy, a reef was taken in the courses, and the topsails were close-reefed. At $8^h\ 30^m$, the wind increasing, the top-gallant-yards were got down upon deck. At $8^h\ 50^m$, "cable was veered" to a cable and a half on the best bower-anchor, by which the ship was riding in sixteen fathoms water. At $9^h\ 40^m$, it was discovered that the anchor had *broken;* the small bower was therefore let go, which brought the ship up in ten fathoms water. The yards and topmasts were immediately struck. The wind from S. W. continued to increase, accompanied by rain. The night was dark, but the lumination from the heavy *sea*, breaking on the Isle-of-Rhe reef, (the length only of two cables from the ship,) was sufficient to afford an awful view of her dangerous position. The best bower was now unspliced, and the inner cable bent to the spare anchor. The slack of the best bower was then hove in to about two-thirds of a cable, when the anchor or its stock, entangled by the rocks, assisted in holding the ship; it was therefore bitted and secured. The ship was now riding by the best and small bower anchors, with two-thirds of a cable on the former, and a cable and a half on the latter, while the sheet, and spare anchors at the bows, were perfectly ready to let go at the shortest notice. A steady leadsman was placed in the port chains to get a cast of the lead every five minutes, and a careful quartermaster stood at the starboard gangway attending the deep-sea lead. The man in the chains soon discovered a large rock, rising three fathoms from the bottom, directly under him; and others were afterwards found, by the lead striking upon them, varying in height from one to two and a half fathoms. This, situated as the ship was, so *near* to the reef, and *without* chain-cables, was a terrible discovery; for in such a position, the hempen-cables could not

possibly hold her many hours longer, more particularly as the rocks caused a most irregular cross-sea, giving to the ship a violent jerking motion; so much so, that the oars were occasionally jerked out of the barge on the booms.

When every preparation had been made—the officers and men in their respective stations, ready to act on the shortest notice—the captain placed himself in the port gangway, to watch the heaving of the hand-lead. The intense anxiety kept up by the soundings, varying from one to three fathoms, may be imagined, but cannot be described. The gale, accompanied by rain, continued with unabated force, and the heavy sea breaking upon the reef astern produced frightful flashes, which, in the darkness of the night, rolling over the rocks, might have been likened to moving masses of liquid fire.

The day had scarcely dawned, when the quartermaster, attending to the deep-sea lead, declared the ship to be driving. The spare anchor was instantly let go, which providentially brought her up again; nevertheless, it was but too certain that the ship could not be held much longer by cables which had been chafing so many hours on sharp and rugged rocks. The wind was now at west, St. Marie Church, on Isle Rhe, bore east. The gale increased; but the favorable change in the wind was counterpoised by a strong lee current, and a heavy cross-sea on the off-shore bow. The sun had already reached the meridian, unaccompanied by any indication of a favorable change in the weather; and the captain, feeling it impossible to sustain through another long night the intense anxiety of that of the preceding, thus addressed the French pilot: "Pilot, can you save the ship?"—"*By gare, no!*" was the desponding reply of the foreigner. Orders were then given to sway up the lower-yards to three-fourths of their *usual height*—to secure the topmasts close down, leaving the topsail-yards to work on the caps—to pass the largest hawser through the starboard quarter-port, and to bend it to the cable on the spare anchor, for the purpose of acting as a spring in canting the ship to port, previously to cutting the cables; but, at the instant of bending the hawser, the cable *parted*, and it was ultimately bent to the small bower cable.

The courses and topsails were secured in three or four places, on their respective yards, with stops of spun-yarn, so as to be cut on the instant; the gaskets had been previously cast off; the head and main yards were braced up for the starboard tack, and the other yards kept square, dividing the men (who would otherwise have been required at the braces) between the fore-tack, and fore and fore-topsail sheets.

It will be seen, that in the event of the spring casting the ship, the head yards would require no alteration, and it would only be necessary to guard against setting their sails *too soon*. On the other hand, if the spring (which was every way probable) broke, the yards could not be better placed for producing the stern-board, which would, in that case, be necessary to clear the reef.

The spring was hove-in to a tolerable strain. The master was directed to attend at the bitts, and see that the carpenters cut the cables the instant the word was given. All being ready, and the greater number of those on board being in the expectation of a watery grave, the cables were cut. The heavy sea on the port-bow acting against the spring, caused it to snap: it was immediately cut by the axe, provided for that purpose, to prevent retarding the ship's sternway; the helm was put hard to starboard—the fore-topmast staysail hoisted—the fore-topsail let fall, and sheeted home—the foresail let fall—the tack hauled on board, and the sheet roused aft. All the sail was flat aback, and *set in less than half a minute*. The

ship's head paid round quickly towards the reef. When the wind became abaft the beam, the mizen-topsail was let fall, and sheeted home, and the helm shifted. When the wind came right aft, the main-topsail was let fall, and sheeted home; the mainsail was next loosed, the tack hauled on board, the sheet roused aft, and the mizen-topsail, cross-jack, and main-topsail yards braced up for the starboard tack.

This manœuvre, from the cutting of the spring till the requisite sails were set, did not exceed *two minutes*. At the moment that the ship's head was in the direction of the rocks, and then only in five fathoms water, the vessel made a desperate plunge, and in hauling to the wind the send of the sea did not leave, by the soundings, more than a single foot of water under the keel.

The ship was shortly afterwards safely anchored in Basque Roads.*

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## TRIMMING YARDS, (HINTS.)

When *close-hauled*, the yards aft must be braced sharper than those forward, and the upper yards braced in a little more than those under them, especially with strong breezes. The leech of the *mainsail*† is always best to steer by when blowing fresh, and when the wind is very light, the *main-royal*. It frequently occurs with an old sea on in light airs, that the sails all flap to the masts with every roll, and render it extremely difficult to tell when the ship is near the wind. If under these circumstances, the officer of-the-deck will occasionally walk to the *lee* side, and cast his eye up on the fore part, or front of the light sails, he can more easily tell when the ship is near the wind, as the difference sometimes amounts to more than a point in the course which the ship might make.

When the wind is *abeam*, if the yards be so braced that the angles between them and the wind may be a point and three-quarters *greater* than the angles formed by the yards and the ship's head, that point will produce the greatest headway. The old French practice of sailing close-hauled for speed, was to brace the yards up sharp—haul well taut all the bowlines, and slack the lee-braces, which no doubt in some measure added to the speed.

In *tacking*, never brace to the head yards, unless it be absolutely necessary to prevent the ship from going ashore, or when she has no headway to come round of herself.

It is necessary that all sails should be trimmed to stand as taut as possible. The more a sail is made to approach to a flat surface, either by or before the wind, the better: the idea that there should be a reef of slack canvas let out when sailing large, (except in the event of scudding, where it is sometimes desirable to make a *lifting* sail,) has long since exploded. It is likewise necessary that the sails should balance each other fore and aft, that the helm may be carried amidships, for nothing can be more absurd than a ship having a large spanker set, while at the same time

* Vide Glascock's *Manual*, page 165.

† As the greatest breadth of beam is subtended by the main-yard, and as the mainsail is in consequence more *athwartships* than any other in the ship, it will necessarily be the first to lift when coming into the wind.

she carries a turn and a half of weather helm.* The sails which tend most to counteract the spanker, when the wind is somewhat quartering, are the lower and topmast studding-sails: these sails by standing out from the ship, act as a lever to neutralize the effect of the spanker.

If the wind is abaft the beam, the after yards should be braced more up than the head yards, that the wind may fill the forward sails.

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## SCHOONER SAILING.

In a gale of wind, a sharp-built schooner is hove-to under the double-reefed foresail—the sheet of which should be hauled as flat aft as possible, not only to prevent the vessel from head-reaching too much, but to keep the sail from shaking,† when she comes up to the wind. While the foresail is kept full, the vessel continues to head-reach, whereby a constant action of the water is maintained on her rudder; and this prevents her from falling off into the trough of the sea. If the vessel is very sharp in her construction, and it is seen that she has a tendency to head-reach too fast, it is then necessary to hook on the weather-sheet, and haul the sail amidships.

In some sharp-built schooners, it is frequently essential to hoist the head of the mainsail, to assist in keeping them to. The helm must not then be put hard down, but a little to leeward, or only as circumstances may require. In sailing such a vessel *by* the wind, when blowing in squalls, it is usual to "touch her up" in the wind; but if the wind should prove variable, e. g. first on the quarter, and then ahead, to luff the vessel in this manner would be attended with danger. Sail ought therefore in such an event to be made *snug;* for if a squall should come suddenly on the quarter, it will be too long a luff before the sails touch; and if it comes out ahead, they will then be thrown aback.

A flat-built schooner is often hove-to under a balance-reefed mainsail; but if this be done she must be very flat, and when she will not lay-to, in any way, under a foresail; so that while she is under a balance-reefed mainsail, she will come up and fall off: the after sail will bring her up in the wind when she loses her headway, and then gathers stern-board, and the helm by being a-lee will cause her to fall off, before she has time to fill and get headway. Then with the wind on the quarter, she runs ahead with violence, until she again comes up as at first, and thus she will continue to come up and fall off. But on account of the flatness of her bottom, and its consequent little hold upon the water, she will drift so fast that the sea will be made smooth, and therefore cannot reach her. But should a sharp-built vessel fall off in this way in the trough of the sea, her decks would be in great danger of being swept.

Shallow-built vessels, and such as have flat floors, are much more liable to be upset in a heavy sea than those of a different construction. This arises from their having so little hold upon the water, notwithstanding their great stability in a river, or smooth sea, where it would be almost impossible to capsize them in carrying sail.

* Vide *Arnold's Lunarian*, p. 284. † Ibid. 306.

Dutch galliots, for this reason, are often upset by a heavy lurch, and when the sea strikes them under the bottom.

One or two points more. It must be recollected that the *lee* sheet of a schooner's topsail should be the first clewed up, otherwise it may get over the lee yard-arm, on account of the sail having proportionally more spread at the foot than square-rigged vessels in general. Again, a schooner's weather-braces must not be too *taut*, from the liability to part, or to carry away the yard, by the spring of the masts, &c. A careful person ought to be at the helm of a schooner in carrying sail in squally weather, when it is necessary to luff and touch the sails. At such times the *square* sails should be furled.

Lastly, in tacking a schooner, much depends on working the lug-foresail briskly. It should be hauled over, while head to wind, as quickly as possible, but *never* to make a *back* sail.

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## ENGAGING.

The subject-matter under this head has been carefully gathered from the best authorities, and is designed especially for the study and consideration of the junior branches of the naval service.

With reference to *position*, (which is obviously dependent upon circumstances,) Fordyce thus enumerates the advantages and disadvantages of both the windward and leeward gages. In *engaging to windward*, the *advantages* consist in the choice of situation and distance, and the power of suddenly changing the side engaged; while the *disadvantages* are difficulty of pointing the guns, and running them in for loading—danger of opening the lower-deck ports—exposure of the men on the upper decks to small-arms,* and inability to return the fire from aloft in consequence of the sails intervening.

In *engaging to leeward*, the *advantages* are precisely the converse of those last enumerated, while the *disadvantages* may be said to be, inability to choose situation or distance, and the probability of receiving shot below the water-line. With single ships, it would seem then that the weather-gage, by giving you the choice of station, and the manner of coming into action, (besides being clear of the smoke and throwing it upon the enemy,) would be the most desirable. In fleet-fighting, however, the advantage is thought to be in the *lee* gage, on account of the facility of dropping disabled ships out of the line for repairs, which being done, they can assume their stations again. Whereas, if any of the ships of the weather-gage are disabled, they cannot beat out of the line to windward; and must either be deserted by their crews for some other vessel, or, from the helplessness of their condition, drift to leeward into the enemy's line, and either be sunk or captured.

* A ship that can depend on her sailing, should never be within musket-shot of her opponent till a decisive act is to take place, if she can engage to her own advantage without running closer. She will thereby have all the benefit derivable from superior seamanship and gunnery, without her officers and men being picked off, and will be ever ready to lay the enemy on board when occasion requires. This maxim, however, applies more particularly to single ships than to fleets and squadrons, where circumstances may throw the line of battle yard-arm and yard-arm, and muzzle to muzzle.—*Economy of a Man-of-War.*

Lord Nelson appears most conspicuous in that mode of attack, which in general secures a victory. The battle of the Nile was doubtless a master-piece of tactical science:* it merits notice from its simplicity, and, if we may use the term, its "infallibility." The manœuvre was, to throw *two* of his ships upon every *one* of the weathermost of the enemy's line, by causing his fleet to divide as they approached them; consequently including each French ship between two of his own. The residue, which were moored in a line ahead, fully expected to see his (Nelson's) ships range up the whole length, and oppose ship to ship. They saw their error when it was too late: being to leeward it was impossible for them to render efficient aid, in consequence of which their defeat was inevitable. In the battle of Trafalgar, in which the immortal Nelson quitted his earthly frame, the combined fleets were drawn up in the form of a *crescent*, and awaited his attack, which was made in a double column, apparently bearing down upon their centre. This novel mode of coming into action kept the enemy completely in suspense—threatening every part of their line. If Nelson's column had turned the same way, they would have been able to do infinite damage in that quarter before the other wing of the enemy could come up to succor their overpowered friends—if the two columns should be cut through their centre, they must destroy it, and effectually separate their two wings, so as to leave them ignorant of each other's fate. Such was the fact: the enemy, though superior in number, lost no less than nineteen sail of-the-line.

Perhaps nothing can place a fleet in a more dangerous state, and render it less able to resist an attack, than making sail before the wind, in a line of battle ahead, to avoid a pursuing enemy. In such a case, whenever the rear of that line can be brought into action, it becomes subject to an accumulating force in consequence of the pursuing fleet thickening upon it, while the van of its own line, being to leeward, must make many tacks, or at least two long ones, before it can succor its rear. The disadvantage must be very great, even if all the ships on both sides sail upon an exact equality. But as this is *never* the case, many of the flying ships will be probably driven completely to leeward, and never be able to afford the least assistance.

### SINGLE SHIPS—DISCOVER AN ENEMY.

Prepare for action—beat to quarters; and if at night, stow the hammocks, and light the decks. Unship the bulkheads—clear the batteries both sides—put on the hatch-gratings and tarpaulins—open the magazine, and wet the passage—sand down the decks—light the matches—filling the tubs with *fresh* water for the men. Get up spare breechings and tackles, as also a sufficiency of shot, shells, grape, and wad. Rig the pumps—place shot plugs at the mainmast—sling the yards and gaffs—rack the tyes and halliards aloft—stopper the topsail-sheets. Have luffs, pendant-tackles, hawsers, and fighting-jiggers, at hand, and preventer-braces up and rove—men at the guns, &c., &c.

### MANŒUVRE AND CHOOSE POSITION.

If both parties are equally well disposed, it is evident that but little time will be lost in coming within range. Should the enemy wish, however, to avoid the action,

* *London Encyclopædia.*

and be to leeward, chase on the same bearing of the compass—if he be to windward, tack when the chase bears abeam. Under any circumstances it will be necessary to have the advantage of sailing, unless the enemy be so imprudent as to venture within range, when some well-directed shot may take effect, and force him to an engagement.

### ENGAGE.

If to windward, and prepared for action, shorten sail, so as to have the ship under command—say, topsails, jib, and spanker, sending down top-gallant and royal yards. Bear down so as not to be exposed to a raking fire, but edge on the quarter or bow. Should you have reason to believe that your range is greater than the other ship's, haul up at long-shot and commence. On the contrary, having carronades, lose no time in getting within point-blank distance. Should your opponent be disposed to try a raking fire by altering his course, luff to, but do not attempt to return the compliment until certain that it will tell. If to leeward, and the enemy bearing down, back the main-topsail, and wait—watching every opportunity that offers to rake him, either by luffing to, or edging off. During the engagement be calm, yet watchful of every movement, and see that the wounded are taken proper care of.

### REPAIR DAMAGES.

Secure the guns and magazine—hook and set taut the runners and burtons—*splice* the standing and *knot* the running rigging. Let the carpenter inspect the condition of the masts, spars, hull, and pumps first, or replace such spars as may have been wounded. Have the shot-holes carefully plugged, and leaded over Overhaul and repair the sails—refit the gun-tackles and breechings—and fill the number of cartridges, &c., &c.

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## STEERING, (HINTS.)

In general, a ship, trimming by the *head*, requires a *taut* weather helm. If, on the contrary, she swims too much by the *stern*, she will carry what is technically termed a lee or *slack* helm.

*When by the wind*, a tremulous motion in the cloths of the *mainsail* will always indicate that the ship is then at the desired point of full and by—for when sailing thus obliquely to the breeze, the dog-vane does not show the true direction of the wind.

*When steering a course*, much of the precision will depend upon the helmsman anticipating, or checking the ship in her inclination to yaw to starboard, or to port; nor must he trust too much to the compass-card. Ordinarily, the compass suffers much agitation from the motion of the vessel, and does not return sufficiently quick to its parallelism to point out the *true* position of the ship's head; whilst on the other hand, the compass, in smooth water, must be touched to be set in motion.

Good steerage therefore requires a quick sight and a nice judgment in the helmsman, and above all, an acquaintance with the *feel* and force of the helm. He must not pore over the compass, but alternately watch the card, and the motion of the vessel's head passing the clouds, the sea, or any other objects which may present themselves to view, more fixed than the compass itself. In blowing weather, the *feel* of the helm and the *force* of the wind are nice criterions to judge whether the vessel be falling off or coming to. As the vessel *comes to* against the helm, it will appear *heavier*, and the wind drawing forward will seem *stronger*. On the contrary, as she *goes off*, and gives way to the power of the helm, it *eases* in the hand, while at the same time the wind lessens in its force as it draws more abaft. To an attentive and nice observer, these circumstances, though seemingly trifling in themselves, indicate the motion of the vessel sooner than the compass.

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## REEFING, (HINTS.)

Without entering upon all the details of this frequent and necessary evolution, the following practical hints may in all probability serve in some instances a useful purpose, by obviating at least an expenditure of time and labor.

In clewing down to reef, luff the ship to, with a steady helm, and meet her when she shakes. Clear away the bowlines, settle the halliards, and *then* round in the weather braces. By adopting this precaution, the sails are more easily spilled, and by hauling on the weather braces, they serve not only to keep the yard in, but to bring it down also, which would *not* be the case were the halliards kept fast until afterwards. Much depends upon the manner in which the sails are laid for reefing; for this reason it is deemed best by experienced seamen to keep the courses *full*, and to brace the upper yards in, sufficient to make the topsails lay "alive;" or in other words, so that the wind will *cut*, as it were, the *weather-leech* in two, and leave the canvas hanging loose.*

On board of merchant vessels, where a single reef is taken in the topsails, with the view of setting top-gallant-sails over them, the practice is simply to take to the slack of the top-gallant clewlines, and let the sheets stand fast while clewing down the topsails. Many who may never have seen this tried would doubtless question, whether the sheets would not part in consequence; and yet the chances are, that these same persons have witnessed the parting of a topsail-tye at sea, where the top-gallant sheets were not injured in the least. But independent of all this, it is evident that if the sheets are *tautened* by hoisting the topsail, (which everybody *knows*,) they will *necessarily* be *slackened* by lowering it.

The reef-earings of the topsails are passed as follows:†

For the first, second, and third reefs, take the earing up from the sail, and pass it on the fore-side of the yard, round the cleat for the purpose, through the cringle,

* To reef, in going large, either luff to, to shake the sails, or you may point the upper yards to the wind by the braces. To close-reef, *clew up*. In the merchant service, in reefing before the wind, the *mizen*-topsail is kept up to becalm the *main*.

† Vide *Glascock*, page 26.

until two, three, or four outer turns (according to the reef) be passed; then reeve the bight through the cringle from *aft* forward, taking a round-turn in the cringle, and passing the end from the cringle, *under* the yard, up aloft over and through the bight, then back over the yard on the fore-side, through the cringle from underneath the yard; slew the cringle well up; pass sufficient turns to secure; expend the end round the yard, ultimately taking a half-hitch round its own parts* close down.

The fourth, or close reef, is passed in a similar manner, with the exception of taking the *first* turns on the *after*, instead of fore side of the yard, in order to cover the other reefs, and to keep the cringle close up to the yard. The *outer* turns to be passed for each reef are as follows: *two* for the first reef, *three* for the second and third, and *four* for the fourth. The use of the outer turns is merely to keep the head of the sail on the stretch; whereas the *inner* turns have the whole strain of the leech to bear when the sail is hoisted and the bowline hauled.

In reefing the *courses*, the better way is to haul them up. The *first* reef-earing is then passed from *forward, aft,* over a small hook seized to the forward part of the strap of the lift-block, having the point of the hook out-board. The legs are then taken with a round-turn around the jack-stay, and a single hitch, with the bight made around the standing-part. The *second* reef-earing is passed outside of the lift, from *aft, forward,* round the yard, clear of the topsail-sheets, and hitched to its own parts.

In reefing a *spanker*, tend the throat and peak halliards, and lower the gaff as far as necessary—hauling on the weather vang, and down on the leech at the same time. Reeve the earing through the cringle—haul it taut, and pass it around the *clew* of the sail, (since if it were taken around the boom the sail could not be brailed up,) putting canvas underneath to prevent chafe. Bring the forward cringle down to the tack, and reef the sail on the foot.

In reefing a *jib*, haul the sail down, and bring the forward cringle to the tack-hook in the boom—the after one to the clew, and pass the earings; then reef the sail on the foot with nettles—points are never used. A better way than this is to take off the *bonnet*.

In reefing a *top-gallant-sail*, the earings are hauled out by hand, and reef-tackles are not used—the points being passed like those of a topsail. This, however, is seldom done.

In *hoisting the sails* after reefing, be careful (particularly if it be blowing fresh) not to "swig" them up too taut, as the reef-bands are apt to be slewed under the yard in consequence, and the sail must necessarily be reefed afresh.†

## REEFING IN STAYS.

Send one watch aloft, and station the other on deck for stays—keep the ship a good full, and when ready ease the *helm down*, and *let go* the topsail-halliards fore

* In most of the works you will find it recommended to hitch the end around the topsail-*lift*. But it would be well to bear in mind that by hoisting the yard the lift becomes *slack*, and as a matter of course the earing likewise

† I speak of the naval service especially, and from my own experience as a "top-youngster," where the main-topsail was *always* reefed properly, but seldom to suit the ideas of a certain "bellowing" luff, who never looked at the *lee* leech to see when it was taut.

and aft—hauling down the jib if necessary. Out reef-tackles, and up booms. Lay out and reef. When the leech of the mainsail lifts, *rise the main tack and sheet.* Down booms, and lay down from aloft. Man the main and mizen topsail halliards—sending the fore-topmen to them also. *Haul taut—mainsail haul,* and hoist away the after sails. Trim all sharp and taut up—*right the helm* when the mainsail fills, and hoist the fore-topsail at *let go and haul.*

Note.—It will be necessary for the watch aloft to work smartly, as the yards cannot be swung with the men on them without danger; besides, the best disposition must be made of the crew on deck. The buntlines and clewlines are omitted, as the yards will come down well enough by *letting go* the halliards. The sails by being becalmed in stays will hoist much easier, and if lowered when the helm is put down, will afford the men sufficient time to take in a single reef.

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## TACKING, (HINTS.)

This evolution, though the most common in the whole practice of seamanship, nevertheless involves points of the nicest judgment, and skill to effect its proper performance. In the first place, care must be taken that the ship be *by* the wind—*not* "rap full," and at the same time a point from what she *might* lay; nor *jambed* up to such a pitch as to have no headway at all; but simply, so that all the sails may draw without trembling, and when the least touch of lee helm will cause her to shake. Again—do not put the helm down *suddenly,* but *gradually*—spoke by spoke, which gives the vessel all her velocity in coming to the wind, increasing her distance to windward, and keeping her under command after the after yards are swung. If, on the contrary, the vessel be suddenly brought to the wind by the helm being put down *all* at once, the ship will most certainly lose her way, and consequently have stern-board before the head yards are touched. This often leads to missing stays. And here arises another point—viz. the order "helm's-a-lee" should *not* be given until the *jib lifts*—for so long as the sail is full, it is manifestly of service to the ship in staying; and when it shakes it is of no use, and then the sheet may be let go. If, on the contrary, the sheet be eased off beforehand, the sail begins immediately to "flap," and so it will continue until it fills on the other tack, or has altogether prevented the vessel from coming head to wind. The same may be said of the *fore-sheet;* and hence it is, that officers who understand this principle, oftentimes run the lee clew of the foresail up to the yard, at the order "rise main tack and sheet," which should be given when the *lee* leech of the mainsail lifts. The fore tack, however, should not be eased until after "mainsail haul," for otherwise the entire strain and pressure of the foresail (and that *aback* too) is thus brought upon the bowline.

If the mainsail be hauled before the wind comes ahead, the main-yard will fly around of itself; but if it be *not* hauled until the wind comes ahead, or on the other bow, it will occasion a very heavy and tedious haul. Instead, therefore, of watching the lifting of the spanker, or the movements of the dog-vane, observe rather,

when the *weather leech* of the *main-topsail* is well *aback*, as the indication when to haul the after yards; and *right* the helm when the wind fills the leech on the other tack. The head yards are then hauled as soon after as possible—observing, first, however, to brace and trim all sharp abaft.

In tacking under *double-reefed topsails*, the practice of bracing to the head yards, *while the ship has headway*, should never be resorted to, as tending to destroy, not only the effect of the rudder, which is of more consequence, but to check the velocity altogether. Under these circumstances, as soon as the vessel comes up head to sea, and loses her way, put the helm *amidships*, and as she gathers stern-board shift it *gradually*. The chances are then ten to one that she will never "miss stays."

Should a squall strike the ship in stays, up mainsail and spanker, in royals and top-gallant-sails, and slack the weather head-braces. If the squall is very heavy, get the vessel before the wind, and clew down; otherwise, let go and haul.

NOTE.—The jib is a *lifting* sail, and the reason why a ship pitches more with it set, than when hauled down, is *not* that it depresses the bow, but because it raises her higher out of the water, and consequently the ship has a greater distance to fall before the water receives her bow.

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## WEARING, (HINTS.)

In ordinary cases, let the weather braces be started *before* putting the helm up, and keep the main-topsail leeches *lifting*;* this will bring the ship around (provided she had good headway at the offset) in a very short space. Observe, however, to put the helm up *gradually*, and to brace the after yards entirely round, by the time the ship gets before the wind—letting go the *lee* head-braces when the wind gets well abaft, as the forward yards will thus fly nearly square, and save some little pulling and hauling. When the wind draws on the other quarter, meet her with the helm, jib, and lee head-braces, as she comes to.

If the vessel will wear readily, in place of taking in, or lowering the trysail altogether, it is better to drop the peak only, and trice up the tack.† By this means, the after part of the deck is not encumbered by a loose and fluttering sail: which, in a brig, is apt to get foul of the wheel, and embarrass the man at the helm.

In wearing in a *gale*, two or three heavy seas generally follow each other, and cause the bow of the ship to fall off. This is the time to put the helm up. The main-topsail should not be shaken, but kept full, so as to give the ship headway, and when she is nearly before the wind, the weather braces can be easily hauled in. If the foresail is furled, let the head yards remain as they are, (viz. aback,) to stop the headway as she comes up to the sea on the other tack—brace the main-yard

* An exception to this occurs in very light weather, when it is essential that the vessel should have headway to help her go off.

† *Outlines of Naval Routine*, page 137.

sharp, haul taut the weather braces; and after two or three heavy seas pass, let her luff gradually to the wind; and when the headway is deadened, brace around all the yards.

### WEARING ON A LEE SHORE.

The following method of performing this evolution is from the lips of an old sailor, who, having witnessed frequent trials of it, in cases of emergency, assured me of its never failing.

Station the crew as if for *stays*. Ease the helm *down*, and when the sails shake, "rise tacks and sheets." As the ship comes up head to the sea, and just before falling off, check the lee braces, and swing all the yards for the other tack, at the same time taking in the mainsail and spanker, and hauling flat aft the head sheets. The ship will now have rapid sternway, and the helm being *a-lee*, with the head yards aback, the bow will pay off roundly and force the stern to windward, as the after sails lose their effect. When the wind draws on the other quarter, haul out the spanker, and set the mainsail to bring the vessel to. As soon as the after sails fill, right the helm, and brace all up sharp.

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## SCUDDING, (HINTS.)

In a very heavy gale and a high sea, it is best to steer with the wind about a point on the quarter, having all the yards braced *square*, and the sails well furled, except the close-reefed *foresail* and *fore-topsail*, with good preventer-braces on the yards, led well aft, and hove taut. Should the gale be so violent as to require less sail, then take in the foresail, and scud under the close-reefed fore-topsail, having the yard on the cap, in order to make a *rising* or lifting sail.* The ship will steer better under this arrangement of her canvas, and be ready, in case of being caught aback by a sudden shift of wind. The fore-topmast staysail (in such weather) with the sheet hauled flat aft to leeward, will be found an excellent guide for the helmsman in steering, as by getting becalmed when the ship's head swings off, he is enabled to see it, and meet her quickly.

In hooking the clew-jiggers, let it be done on the *forward* side of the sail, as it would be impossible to clew up in the event of being caught aback, if they were otherwise. With a heavy sea, the danger to be apprehended is, that the waves travelling faster than the ship, may overtake and break over her. In deeply-laden ships and small vessels, the liability is perhaps greater, and it is often found advantageous to tow a hawser, or light spar, over the stern, in order to break the sea.

Another point in scudding is, that a vessel should not run too long, as she is thus exposed longer to the gale, which may have blown by at her original position, and be only following in her wake. The hooking of rolling-tackles should not be neg-

* This is done that a portion of the strain may be taken from the *lifts*; and is decidedly preferable to the plan of easing off the sheets.

lected. In ordinary cases these should be hooked on the *weather* side, in order to keep the yard to leeward—for it is manifestly impossible to prevent it from going in that direction. If, on the contrary, the tackle is hooked on the lee side, the pressure of the yard would, in all probability, part the strap; besides, the fall would chafe against the lee rigging. In scudding, however, in heavy weather, where the yards are squared, they should be hooked on both sides. It is under such circumstances as these that a parrel is often carried away; and for this reason each top should be supplied with a long stout strap and jiggers, which may be employed, in the event of accident, by passing the ends of the strap over and under the yard, (having the bight abaft,) and hooking on the jiggers.

Note.—No reference, it will be perceived, is made to "broaching to," or being "brought by the lee." For the reason, that if a ship be scudded under the fore-topsail, there is little or no danger to be apprehended of such an accident—provided she is a good steering ship, and careful helmsmen are employed at the wheel. If, on the contrary, she steers badly, or is badly steered, she has no business to scud. Finally, in lieu of using a heavy sluggish compass, take rather a light and sensitive one, which will indicate far quicker every inclination of the ship's head to starboard, or to port.

### SPLIT THE CLOSE-REEFED TOPSAIL—BEND ANOTHER.

In a case of this kind, as a general rule, it is recommended by experienced seamen to bring to, under lower staysails, which must be set according to the known qualities of the ship—the lee braces manned, and a smooth chance watched to give her the lee helm. As this is done, haul taut the lower lifts, brace up, and ease away the weather topsail-sheet, hauling up both buntlines at the same time—then clew up to leeward, and brace the yard well in to clear the lee rigging, and to give the men a chance to furl and unbend. Roll the sail up, and begin at the yard-arms to cut every other roband, and cast off the reef-points. Pass the latter, and the sea-gaskets, (after the manner of a furling-line,) around the sail as snugly as possible. Unclinch the reef-pendants and sheets—unreeve the clewlines and clew-jiggers, and untoggle the buntlines and bowlines. Hook the sail-tackle (a stout burton) to the topmast-stay collar, overhaul it down, and hook it to a strap around the bunt of the sail. Cast off the remaining robands, and bring the lee head-earing in, making it fast to the standing-part of the sail-burton at the block: sway taut, cast off to windward, and lower away on deck.

A simple and secure method of sending a topsail up or down, in heavy weather, without the trouble or necessity of a tripping-line, is to make the top-gallant-yard rope answer the purpose of a jack-stay, by belaying the bending-end to the bitts, and swaying taut on the hauling-part; in which case you have only to knot the ends of a small piece of rope through the strap on the sail, and around the yard-rope, to serve the purpose of a grommet. Having now sent down the old sail, prepare the new one on deck by reefing it on the foot with *spun-yarn*, or *nettles*, and *not* with the points, as is sometimes recommended; since the men cannot cast them off without great labor and difficulty. Bring all the gear into the top, except the reef-pendants, which have in the slings of the topsail-yard, with the top-burtons hooked, to haul out by, unless yard-arm jiggers are used instead. Take in the reefs, beginning at the foot, and make the sail up on the leech like a studding-sail. Pass a strap

around the bunt, hook the sail-tackle to one bight, and seize the other to the back of the hook, and *not* to the *strap*, which brings all the weight and strain on *one* part. Put in the robands—connect it with the yard-rope, as in the case of sending down the old sail, and sway away until it gets up to the top. Clinch the sheets, reeve the clewlines, hook the clew-jiggers, toggle the buntlines and bowlines, and sway away. When high enough, take a turn with the sail-tackle, clinch the reef-pendants, man the burtons, or yard-arm jiggers, (if used instead,) and haul out. Slack handsomely; get the sail in the centre; pass the midship roband, and have the sail taut along the yard. Pass the head-earings and remaining robands, and prepare to reef. Haul the reef-cringles well up, cut the strap-seizing clear from the hook; take to the slack of the buntlines and clewlines, (to keep the sail from flapping,) and get the band taut along the yard—out earings, and pass the points, having the after legs taut, which precaution is always necessary in a snug reef. Cut the stops of the remaining reefs as requisite, and pass them in the same manner, except of course the last one, which must be taken underneath the yard, observing to gather up the slack of the buntlines and clewlines. When reefed and ready, brace the yard so that the sail will stand nearly "alive" when set—man the lee sheet, ease away the gear, and get it well down—then sheet home to windward—haul the lower and topsail lifts, and reef-tackles taut, to steady the leeches, and relieve the tye and earings. Take in the staysails, watch a smooth chance to give the ship weather helm, brace in, and get her on her course as before. Bouse your rolling-tackles and braces taut, and lead along your topsail-sheets and clew-jiggers clear for use. Send down the sail-tackle.

Note.—Instead of using the burtons to haul the earings out by, in the ordinary cases of bending, recourse is sometimes had to the topmast studding-sail halliards, if rove and hitched to the clew of the sail, as is usually the case.

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## GETTING UNDERWEIGH.

The minutiæ of weighing anchor in an open roadstead, and from similar positions, is so simple, that it is deemed unnecessary to refer to it here; nevertheless there are circumstances which arise from peculiar situations of wind and tide, and other natural impediments, which are worthy of a more significative allusion. First, then,

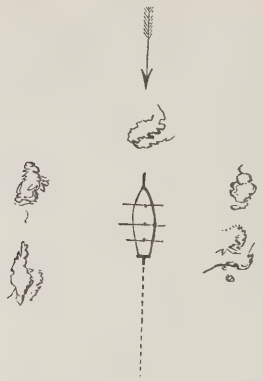
### TO BACK OUT.

This evolution supposes the existence of danger upon each quarter and ahead, and also a fresh breeze and strong leeward tide—a *question*, doubtless familiar to the mind of every quarter-deck youngster, a "banyan-day" old in the service.

Loose sail, and take two reefs in the topsails, having previously hove in to a short scope of cable. Sheet home, and hoist away—keeping the yards *square* fore and aft, and the helm *amidships*. Heave round again, and as the anchor breaks ground, and the ship begins to move, pall and stopper the cable immediately. The anchor

being now just clear of the bottom will drag, and keep the ship head to wind, while drifting stern-foremost. When clear of the danger, heave up briskly, and wear short round—making such sail before the wind, as the exigencies of the case may demand.

Fig. 3.



NOTE.—Should the anchor take the bottom in driving thus, and bring the ship up, weigh it off the ground, and let it hang as before, until the ship is clear of danger.

### HEAD TO TIDE—WIND TWO POINTS ON THE STARBOARD BOW—WEIGH AND CAST TO STARBOARD.

Make all necessary preparations, and heave in to a short stay. Loose the topsails, courses, jib, and spanker; set the former, and brace the after yards up with the starboard braces, and the head yards abox with the port braces. Man the jib halliards. heave round, and put the helm a-*port*, to sheer the ship to the wind. As the anchor breaks ground, run up the jib, (hauling aft the *port* sheets:) when a-weigh, the tide having her on the port bow, and the head yards being sharp aback, she will pay off rapidly to starboard. Then proceed as in getting underweigh, head to wind.

### HEAD TO TIDE—WIND ON THE STARBOARD QUARTER—WEIGH, AND CAST TO PORT.

Heave short; loose sails, sheet home, and hoist the topsails, pointing the yards to the wind with the starboard braces. When the anchor breaks ground, put the helm to starboard; brace full the head yards, and hoist the jib, when the ship will fall off to port rapidly. Haul out the spanker as soon as it will take; shift over the jib-sheet, and square the head yards. Trim aft the jib-sheet; meet her with the helm; cat and fish the anchor; fill the head yards and make sail.

### EBB TIDE—WIND ACROSS.

Heave short, loose sails, and set the topsails; brace up, fill the fore and mizen, and leave the main square. Then heave up—cat and fish the anchor, keeping the ship to, and either tack or wear. Tacking or wearing will, however, depend on

circumstances, and the amount of room to windward or to leeward. It matters little whether you have headway from the anchor or not, the position must determine, and the jib alone will be sufficient until well off.

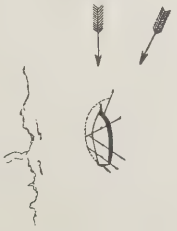
*If to tack*—hoist the jib, fill away the main-topsail, haul out the spanker, and set top-gallant-sails, &c.

*If to wear*—hoist the jib, up helm, shiver the after sails, &c.

## WEIGHING FROM A LEE SHORE.

This supposes the conditions of a vessel which has rode out a gale on a lee shore, from whence it is desirable to weigh and stand off; but where a strong current sets along the land, and where the wind blows in on the off-shore bow, as indicated by the arrows in the accompanying cuts. Under these circumstances there may be two methods of getting underweigh.

Fig. 4.



*Case* 1*st* represents the position of the ship riding by the starboard cable. Make the accustomed preparations, and heave into a short scope without tripping. Bend a spring from the port quarter to the cable, and make sail to topsails, mainsail, and spanker—bracing the after yards sharp up by the starboard braces, and the head yards abox—or rather pointed to the wind. Put the helm hard a-*port;* stream the buoy; slip the cable, and heave in smartly on the spring, which will bring the chain on the other bow, and cast the ship to starboard. When the after sails take, hoist the jib, right the helm, slip the spring, and trim the head yards, as necessary.

Fig. 5.

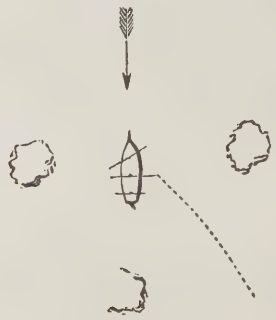
*Case* 2*d*, in which the position of the ship is again illustrated. Here, in lieu of slipping and using the spring, the anchor is hove up, and the ship backed off, by putting the helm to starboard, instead of port, as in the previous case, while the head yards are braced sharp abox, and the after ones kept nearly square. In this case, the mainsail is not used, and the foresail set to help the ship's head pay off to

port. When sternway commences, the helm is shifted to port, the after yards trimmed sharp by the starboard braces—spanker and mainsail set, &c., &c.

### RIDING TO A LEE TIDE—DANGER ASTERN, AND ON EACH BEAM.

Heave short without tripping—loose sails, and set the *fore*-topsail, and fore-top-gallant-sail; lead along the halliards of all the head sails, as also the fore-tack and sheet, and brace the forward yards sharp up by the port braces.

Fig. 6.



Masthead the after yards, keeping them square, and stopping the sails up with rope-yarns. Put the helm hard *a-port*—heave up briskly, trip the anchor, let fall the foresail, hoist the jib, with the sheets to windward, and wear short round on the ship's heel, shifting the helm when necessary. When before the wind, check the port head-braces—make after-sail, and stand out with the wind on the quarter.

Note.—Let the spare bower be kept ready to let go in case the ship should cast the wrong way; and observe to give her a rank sheer with the port helm, *before* the anchor breaks ground, hoisting the head sails as soon as the vessel passes the direction of the wind.

### WIND AND TIDE CONTRARY—SHIP ACROSS THE STREAM.

If to get *before* the wind, square the after yards, and brace abox the forward ones. Heave up the anchor, and when the head sails shiver, square the head yards.

If to make sail *by* the wind, brace sharp up the after yards, square the head ones—heave up the anchor, and when the ship comes to, brace up forward.

### RIDING TO THE WIND—TIDE AFT—WEIGH, AND GET BEFORE THE WIND.

Make all necessary preparations, and heave in to a short stay. Loose the top-sails, courses, jib, and spanker, and set the two former. If riding by the *port* cable, brace the head yards abox, with the port braces, keeping the after yards square. Heave away the cable, man the jib-halliards, and put the helm to *starboard*. Anchor a-weigh: hoist the jib, and haul aft the starboard sheet. Heave up briskly, cat and fish; and when she has fallen off so as to fill the after sails, and gather headway, shift the helm, and brace full the head yards. When before the wind, right the helm, square all forward, and make sail.

### STRONG WIND AND LEE TIDE—WITH A SHOAL ASTERN.

With regard to the manner of executing this manœuvre, there seems to be a difference of opinion among sailors and tacticians; it is, however, generally conceded, that the following method is by far the most certain and secure:

Fig. 7.

Heave in to a short scope of cable, and make sail to single-reefed topsails; lead along the tacks and sheets, jib-halliards, and spanker out-haul, and brace the yards as sharp up as possible by the *port* braces, and put the helm hard a-starboard. As soon as the anchor is a-weigh, let fall the courses, set the spanker, meet the ship with the helm, and hoist the jib.

Note.—This supposes the case of casting to *port*. If to starboard, reverse the yards, and put the helm the contrary way.

### WEIGHING ANCHOR IN A BOAT FITTED WITH A WINDLASS.

Rig the windlass and cylinder, and if the buoy-rope can be trusted, reeve the end of it up through the pipe in the bottom of the boat—take it around the barrel and heave up. Then bring the boat under the bow, and sweep a stout strap, with a small line made fast to each end under the bottom, so as to cross the parts, and take a round-turn around the shank of the anchor. Bring the ends up on the same side—hook the fish-tackle, and walk the anchor up, crown first, until the ring is high enough to hook the cat. Should it be desirable to get the anchor up *ring* first, it may be done by sweeping the stream-cable under the boat, (so as to catch between the stock and the flukes,) forming a running clinch with the end around the other part, and hauling through the slack—then heave in on the cable—ease off the buoy-rope—haul the boat out of the way, and hook the cat to the ring when high enough. If a portion of the cable should be attached to the anchor, sweep under it—take the end through the hawse-hole, and heave in.

Note.—Should the buoy-rope not be strong enough to weigh the anchor, form a large running clinch (to catch the upper fluke) around it, and let it run down. Then jamb it taut, and heave up. A jury windlass may be rigged in the absence of a proper one, by having a round spar secured athwart the boat, and working it with selvagees and heavers—having the hawser, or buoy-rope, or cable, led over a davit at the stern.

## PRACTICAL HINTS.

The following practical hints have been carefully selected from the best American and English authorities :

Before getting underweigh, shift the helm over two or three times, to ensure the rendering of the wheel-ropes, and that the tiller is clear in its sweep. Have a leadsman in the chains, and the ends of the hawsers clear for pointing, as may be necessary. Range the spare bower cable, having the anchor ready for letting go, and examine the cat-head and shank stoppers.

In purchasing the anchor, have a stout deck-tackle in readiness, as also a lashing-block, to assist the messenger, if requisite, and reserve new and dry nippers for the moment of bringing up and down. Under such circumstances, as the heave is often heavy, particularly in an anchorage of stiff clay, a "collier's purchase" may be used to great advantage. This is formed by hooking the cat-block to a strap on the cable near the water's edge, and clapping on the fish-purchase to the fall, which should be taken to the capstan or windlass. In this way the nip and friction of the hawse-hole is avoided. Glascock recommends putting 'the whole strain of the ship on the anchor that is weighing, by veering to three or four fathoms after the cable is *said* to be up and down.' In bringing to, (if there be much wind or sea,) use *racking* nippers—care being taken not to unbit or unstopper the chain *too soon*. If, on the other hand, there be not much wind or sea, and little strain on the cable, bring to, by commencing to pass the nippers at the hawse-hole, and working aft. Then heave in, and when the bight of the cable is taut from the cavil, unbit, and get both messenger and cable on the *upper* side of the cavil. If a nipper jambs, stopper before all, and walk back the capstan, whereby the strain is brought on the stopper, and the nipper relieved. To prevent surging, the turns ought to be kept close and steadily up, and hands stationed at the capstan with flattened levers, to pry the eyes and lashing up when passing round the welts.

If the anchor should come up *foul*, send a hand over the bow with a stout strap, which must be put around the shank close under the stock, and the cat-block hooked to that in lieu of the ring.

When the wind, tide, and locality of the anchorage admit of the vessel's casting clear of the shore, shoals, and shipping, it is recommended to defer the operation of loosing sails until the anchor be hove up, catted, and fished, and all the running ropes are coiled, and fairly led, for putting canvas on the ship. The late Captain Arnold (a most experienced seaman) says, in reference to this point, 'It must be remembered, that a ship which has to *wear* in getting underweigh, will seldom readily pay off until the anchor is close up to the bow. Therefore, under such circumstances, heave up as briskly as possible.' The same author remarks : 'If a ship has a leading wind, and is anchored in a narrow channel, or in the midst of a number of vessels, she should be got underweigh before the *weather tide* is done, as it would be extremely difficult to cast her upon the lee tide. Should it blow fresh upon the windward tide, so as to force her "end on" with her cable, it would be impossible to heave it in without sheering her over from side to side, and heaving in briskly as the ship slacks the cable; but as this would be attended with considerable danger by the sudden bringing up of the ship upon each sheer, it would be

prudent to heave a-peak upon the first setting of the windward tide, and before the ship swings to bring the wind aft.'

Lastly, if the ship be towed by a steamer, and *two* tow-ropes are employed and worked at the capstans of the vessel towed, care must be taken to attend the palls; for when a sudden strain comes upon the acting hawser, and the palls of the capstan are not ready prepared to catch, and support the weaker power, the capstan may revolve round at a rapid rate, endangering the limbs and lives of men upon the quarter-deck.

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## ANCHORING.

Before treating of the evolutions peculiar to this branch of tactical seamanship, it is thought proper to preface them with a few appropriate quotations from the works of scientific men, who have written upon this subject.

### PROPERTIES OF THE CHAIN-CABLE.

Great as the advantages undoubtedly are in favor of chain-cables, others of an opposite character require to be noticed. First, for equal strength, the chain will be found heavier in the proportion of 16.4 to 6.7. This additional weight renders more labor necessary to heave it up in deep water with the weight of the anchor added, and it likewise requires great caution to restrain the velocity with which it and the anchor together descend to the bottom, endangering the anchor when the ground is hard, and likewise rendering it probable that the chain will entangle itself with the anchor, as the momentum drags out much more of it than is required for the perpendicular depth of the water.

Another disadvantage is to be found in the non-elasticity of the chain. This is a very serious feature in its character, and requires a peculiar and attentive management, which, if disregarded, may involve the safety of the ship. Although several mechanical contrivances have been proposed, none have been adopted to compensate this evil, which, however, may in a considerable degree be obviated, and the danger removed, by a determination never to ride a ship by a short scope of chain-cable. This precaution, it is to be feared, is little regarded; for, in addition to the numerous disasters daily occurring by ships parting their cables, it is notorious that many masters of vessels make a merit of riding out a gale of wind with no more than thirty or forty fathoms of chain. Several cases of the kind are described in a small pamphlet, recently published, on the merits of "*Porter's Anchor*;" but whatever merit may be due to this or any other anchor in riding out a gale of wind, none can be awarded to such management of a cable; for it may be inferred, that the majority of masters of ships consider fifty fathoms of chain sufficient to constitute a long scope.

It must be in the recollection of many old seamen who served in the navy before the introduction of chain-cables, that we were not in the habit of using a short scope at any time, either when anchoring for a tide or a shorter period. Half a cable

(fifty fathoms,) was the common quantity, and this, too, with the advantage of an elastic material. It is the more remarkable now, when the valuable substance of iron is universally adopted, which, from its peculiar non-elastic character, requires a greater length of chain to ensure safety, that we should adopt the contrary system of using less.

I have no doubt that by far the most numerous cases of parting a chain-cable, or breaking the anchor, are caused by a sudden jerk; but a long scope will in a great measure render a sudden jerk harmless, as it is only to be dreaded when riding short, or veering chain under the pressure of a heavy strain.

With those who consider a long scope unnecessary, the idea is founded upon the great weight of the chain, which favors the very prevalent opinion that the curvature or deflection of it is considerable, even when used in deep water, and with a severe strain; that all the chain near the anchor rests upon the ground undisturbed by either the pitching motion of the ship, or the tension which she causes, and therefore it is useless to veer more. This is indisputably a fallacious notion, and the point I particularly wish to consider—indeed, the principal reason for introducing the subject; the question therefore seems to resolve itself into this: "What is the curvature of a chain-cable when under the pressure of that kind of strain so nearly approaching the breaking point, that it appears doubtful whether it will do so or not? Does the curvature of it at any time, or under any circumstances, when so strained, make a near approach to a straight line?" That is the question, and it is much easier proposed than decided; for although the curve may be calculated by the law of catenary, yet it appears very desirable to have experimental proof.

The daily practice of testing chain-cables at the Woolwich Yard has afforded repeated opportunity for measuring the deflection of all the various kinds of chain at the testing strain, which is much less than the full strength of the cable; but as it has been carefully calculated at 630 lbs. per circular $\frac{1}{8}$ inch, in strict proportion to weight and strength of the various sizes, it is considered a better guide to the experiments than any other, for the actual curvature at the breaking strain: that which would decide the question, and which of all other things it is most desirable to ascertain, never can be experimentally determined, on account of the risk of approaching the spot at the moment when the strain is the greatest. The utmost dip or deflection in all the experiments made was $1\frac{3}{4}$ inches, and the mean $1\frac{3}{8}$ inches, on a length of seventy-five feet; therefore, by taking the greatest as most favorable to those who advocate a short scope of cable, it will produce a downward curvature of ten feet upon a length of one hundred fathoms.

This deflection has been calculated with the greatest care, and proved by several experiments upon chain of various sizes, and in different positions. The depth of water was ten fathoms, and one fathom more for the height of the hawse-hole above the surface; the length of cable from the bow to the anchor was one hundred fathoms; the diameter of the chain $1\frac{1}{2}$ inches, and the strain $40\frac{1}{2}$ tons.

In a common gale of wind, which, I have no doubt, would produce the strain here mentioned, not one link of the one hundred fathoms of chain will quietly rest upon the ground; on the contrary, it will be found by experiment, on a depth of ten fathoms, that 127.98 fathoms of chain are required to form a semi-catenary when suspended in air, and 137.03 fathoms when in water, the buoyancy of which must at all times have its influence. If the strain in riding a ship be less than that mentioned, the curvature will be greater, and no danger need be apprehended; but

in a severe gale, the force of which may be supposed equal to, or nearly equal to a breaking strain, it must be evident that a long scope is the only way to prevent a fatal result.

In the summer of 1823, Her Majesty's ship "Ramilies" was placed in the Downs as a stationary ship. She was anchored on that part of the ground usually occupied by ships of war, rather to the southward, in ten or eleven fathoms water, and moored with ninety fathoms of chain on the best bower to the S. W., and seventy-five fathoms on the small bower to the N. E. Nothing connected with the anchorage occurred during the summer months, but on the 17th of October, during a S. W. gale, the ship parted from her best bower anchor; and on the 19th was moored again with one hundred fathoms of chain in the same direction, and in the same spot as before. On the 21st, in another S. W. gale, the ship parted from her best bower anchor a second time, and in both cases it was found to be the ring of each anchor that had broken; but as they were the large original rings constructed for hempen-cables, they were totally unfit to be used with chain, because, with a hempen-cable of twenty-two inches, the strain is applied to a large portion of the surface of the ring, but with a two-inch chain-cable the strain is confined to a very small section: in proof of which it was found that the fracture of the ring on the 21st had taken place immediately under the shackle, and opened sufficiently for it to be drawn through, when it closed again with the natural strength of the iron, so that the fracture afterwards was hardly perceptible. On the 23d, the ship was moored a third time, with one hundred and sixty fathoms of chain on the best bower to the S. W., and one hundred and fifty fathoms on the small bower to the N. E. With this scope of cable, the ship maintained her position through all the gales of wind which afterwards occurred, although many of them were much more severe than either of those previously mentioned.

In both gales of wind, on the 17th and 21st, it is evident the amount of pressure on the ship exceeded the means and strength of security: what result might have followed in this case, if the anchor-rings had been of the proper shape and dimensions, can only be conjecture; and therefore part of the weakness is undoubtedly due to their imperfect form, but by far the greater portion of it is attributable to the insufficient scope of cable to compensate its non-elastic character: the strain which produced the accident, in all probability was equal to or exceeded the testing strain of the cable. The length of a semi-catenary with that strain, and the same depth of water, is given as one hundred and thirty-seven fathoms, which greatly exceeds the length of cable used at the time alluded to, and clearly points to the cause of the accident; which is subsequently proved by the simple fact, that the same ship, with one hundred and sixty fathoms of chain, maintained her position on the same ground, free from all accident, in gales of wind more severe than either of those which forced her from her anchor when trusting to one hundred fathoms. This evidence appears to be decisively conclusive upon the value of a long scope of chain. The hemp-cable is well known to possess the valuable quality of elasticity sufficient to accommodate itself to any variety of strain when used as a cable, but the chain is, on the contrary, so stubborn and unyielding, that nothing but a long scope can render it safe; this is equivalent to additional strength; it admits the ship to rise over each successive wave under the constant pressure of a great strain, preventing entirely the danger of sudden jerks, which, of all other trials, is the greatest and worst to a chain.

It has been remarked, with reference to the experiments upon the full length of one hundred fathoms of chain-cable, that although the curvature of it is no doubt perfectly correct in proportion to the strain, and the depth of water, yet in a gale of wind the full strain would not be constant; the violence of it is frequently relieved by long intervals of lull, during which time there would be no risk whatever. This may all be very true; but the argument does not apply to the scope of cable: the greater danger is to be watched and avoided, not the less; for, however long the intervals of lull may continue, let the breaking strain be applied but for a moment, and the result must be fatal.

It is to be hoped that enough has been stated to satisfy the skeptic and doubtful; if not, it is useless to say more. Any man in charge of a ship at anchor, with the necessary quantity of chain-cable on board, and space astern to allow him to make use of it, but who neglects to do so, must be considered the author of his own misfortune, whether it may amount to the loss of his anchor, or the loss of his ship. No excuse can be offered for such neglect, which must originate either in indolence, or in a mistaken notion of the necessity.*

### BEATING IN FLOOD TIDE—COME TO ANCHOR.

Always come to with the head of the ship to that which is the stronger, either the wind or the tide. Let the last tack be that which will bring you close to the weather shore—reduce sail to the jib—put the helm *up*, and wear short round till the ship's head approaches the flood tide, then down jib—let go the anchor, and furl sails.

### WIND FREE—TIDE EBB—ANCHOR HEAD TO TIDE.

Make all preparations for anchoring the ship, and reduce sail to topsails as she approaches her berth. When near the desired position, clew up, haul down the jib, and stream the buoy. As the tide checks the headway, let go the anchor, and veer to the proper scope. If squally, pass in the leeches of the sails, and furl before anchoring.

### ANCHOR HEAD TO WIND IN A NARROW CHANNEL.

Stand in close to one side of the channel, and when nearly abreast of the berth, clew up the fore and main topsails, at the same time hauling down the jib. Put the helm down—haul out the spanker, and brace the mizen-topsail aback. When head to wind, let go the anchor, and clew up.

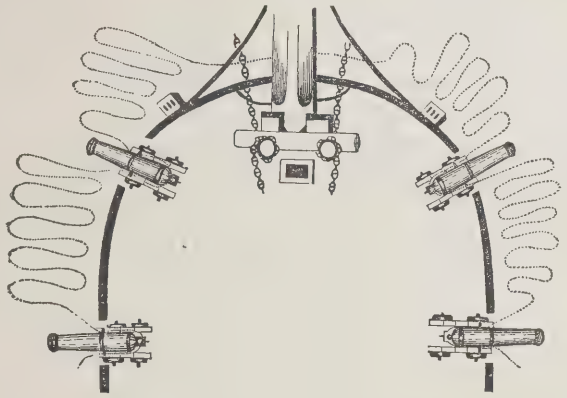
### ANCHOR ON A LEE SHORE.

Bend all the cables, and make such other preparations as may be necessary from the circumstances of the case. Take in the square sails as quickly as possible, and bring the ship under lower staysails, bracing the yards all full. When ready, give the ship sufficient weather helm, to keep headway on her, and maintain her in

* Vide Tinmouth's "*Inquiry Relative to Points of Seamanship.*"

a line as nearly parallel with the shore as possible. Then let go the weather sheet, weather bower, lee bower, and lastly, the lee sheet, observing to pay out chain, so as not to check the ship, and round her to, when the last anchor is let go. Then veer, and bring a strain on all, and prepare to back the anchors with guns.

Fig. 8.



This may be done by passing a stout hawser underneath the cables, forward of the hawse-holes, and bringing the ends (aft on each side) in at the ports, under the pomillions of the guns to be thrown overboard, (which should be those *forward*, in order to lighten that part of the ship;) having the hawser secured just forward of the trunnions by a stout lashing, and leaving a bight between each port, sufficient for the gun to reach the bottom, as illustrated above. Now when the ship drags, the bights of the hawser will catch in the flukes of the anchors, and materially assist in making them hold: moreover, after the gale is done, if the ship should ride it out in safety, the guns can be more easily weighed thus, than if thrown overboard in any other manner. Finally, send down lower yards, (except the *fore*,) and strike the topmasts. The former may be done as follows:

Sway up and hook the pendent-tackles to a stout strap over (or to the eye-bolts in) the lower cap; round up the lower blocks a little above the yard, and hook them to stout selvagee-straps around each quarter outside of the blocks in the slings; take the falls through leaders hooked to eye-bolts at the foot of the mast, and man them well; single the lifts, (if double,) and have hands to attend them; make the top-bowlines fast around each quarter of the yard to keep it clear of the mast, or use the yard-tackles hooked to the slings, and to eye-bolts well forward. Unkey the trusses, and unreeve the topsail-sheets—sway up, and unhook the slings. Lower away, resting the yard on chocks on the rail.

In striking the topmasts, hook burtons on the topsail-yards, cast off the parrels, and lower them in the top, where they should be secured. Come up the rigging and stays,* and see all clear. Man the tackle-falls, and sway away—out fids and lower, hauling down on the rigging and stays—when low enough, take a turn with the falls—pass a lashing through the fid-holes, and around the lower-masts. Haul

* Care should be taken under these circumstances—viz. head to wind and blowing fresh, not to overhaul too much of the fore and aft stays, as the masts are thus apt to bind in the cap, and otherwise jamb.

every thing taut—stop the rigging in snugly—set taut the fore-and-aft stays—"sheep-shank" the backstays, and set them up also.

If, after all these precautions, there should be no possibility of saving the ship, cut away the main and mizen masts*—set the foresail, with the yard braced abox—put the helm up, slip the cables, and run the vessel ashore, head on, and not *diagonally*, as sometimes recommended, with the false view of making a *lee* for the men, for even if the vessel should by *chance* cant with her deck towards the shore, the breaking of the sea around the counters and stern would create an eddy, which the efforts of the strongest swimmer could not possibly resist.

Many plans have been devised by ingenious persons for carrying a line from a stranded ship to the shore; and among others, (perhaps the most feasible,) is one contrived by an English gentleman, a Mr. Ward.† The method proposed consists of an ordinary kite, suspending and carrying a second line, and therefore admitting of several trials being made in case the first should fail. This second line is rove through a loop near the belly-band of the kite, and has a small weight attached, which brings the cord to the ground when the kite reaches the land. By means of this, a tow-rope may be hauled ashore, and subsequently a hawser, &c.

Note.—When endeavoring to claw off a lee shore, sail should not be shortened without the most pressing and urgent necessity, even though you make nothing by it; for should the wind change but a single point, the slant may be sufficient to enable you to stand off without having first to make sail, and during which operation, the wind may have hauled back again, and precluded the last and only chance of escape.

## HINTS.

In coming to anchor, let the ship be always got under easy sail, which should be taut up—the sheets close home, and the yards properly trimmed. Heave the lifts and gaskets forward of the sails, and see that all towing ropes are hauled in. Stow the trysails neatly in their cloths, and such of the head sails as are not required. Have leadsmen in the chains, and a rope in each fore-channel for boats; tacks and sheets singled, clew-jiggers hooked, chafing-gear off, boats clear for lowering; and if the wind should be free, see also, that the *bowlines* are let go.

If in standing in, you discover a vessel, or other danger, close aboard of you, and you are too near to pass, either to windward or to leeward, heave all aback immediately, and make a stern-board until clear, then fill away and stand on; but *never* let go the anchors while the ship has any amount of headway.

In anchoring in a place which is unknown to you, and where there is no great depth of water, the *time of tide* should be calculated at once and allowed for, especially if a considerable rise and fall is anticipated, as the ship might otherwise ground, and be lost in consequence.

On board of merchant vessels, in coming to in *deep* water, the general practice is,

* Before cutting away the masts, "a hawser should be rove through the lanlards of the lower rigging on each side and brought in-board, and thoroughly secured. By this precaution, the lanlards may be immediately disengaged from the channels—for when the mast goes over the side, the outer batten, or ledge, which confines the chain-plates, will be torn off, when, the batten falling in the water will preclude the possibility of cutting or disengaging the lanlards of the rigging."

† See full account and illustration in Redfield's *Family Magazine*, Vol III. p. 275.

to "cock-bill" the anchor, and let it go with the chain *bitted*. The object of which is, to avoid, as far as possible, the mishap of a *foul* anchor—as the weight of the chain not unfrequently causes the running-out part to fall over and foul the stock.

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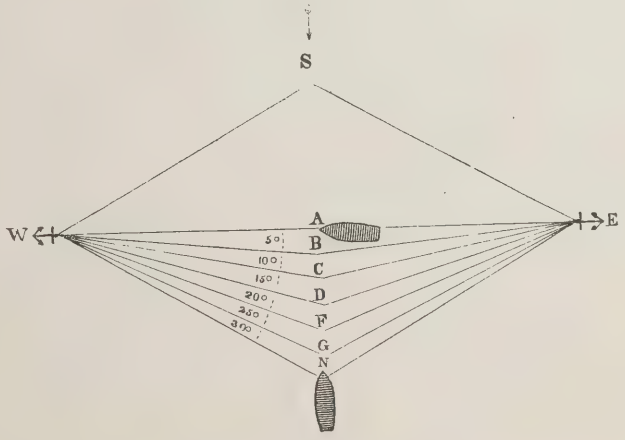
## MOORING.

The following remarks on the nature and properties of a span, in its application to mooring ships, are taken from Tinmouth's "*Points of Seamanship,*" and will be understood by every intelligent mind.

Fig. 9.




Suppose a ship to be moored with one hundred fathoms of cable to each bower anchor in an east and west direction, as illustrated above; and that in calms, or light winds, she would ride in the direct line between the two anchors, as at A. With the wind at east or west she would of course be sustained in position by the strength of one cable; but the seaman who does not consider the subject theoretically might be led into the supposition, that with a south wind blowing in the direction of the arrow, the ship, then, as she rides between the two anchors, would be sustained by the strength of two cables. This is an extremely deceptive and fallacious idea, calculated to favor the notion of security at a time when the position is the weakest, and most unsafe in which a ship can be placed. In mooring a ship, there are generally a few fathoms of slack cable, sufficient to admit of her falling to leeward of the direct line, between the two anchors, when the wind blows at a right angle with that line, as in the case alluded to. The amount of support which the two cables would afford, in each of the positions, B, C, D, F, G, N, having been calculated geometrically, the results obtained may be depended upon.

It is improbable that a ship could be maintained in the position B, at the small angle of 5°, even under the force of a moderate breeze, and with the unyielding character of chain to ride by; but supposing it to be possible, then the whole amount

of support which the two cables would give to the ship, is $\frac{17.4}{100}$ parts, or about one-sixth of the strength of one cable, and no more. At an angle of 10°, in the position C, it would amount to $\frac{34.7}{100}$ parts; at an angle of 15°, in the position D, it would amount to $\frac{51.7}{100}$ parts; at an angle of 20°, in the position F, it would amount to $\frac{68.4}{100}$ parts; at an angle of 25°, in the position G, it would amount to $\frac{84.5}{100}$; and in the position N, at an angle of 30°, it would amount to the strength of one cable; that is, one cable laid out in the direction of the wind at south, would yield the same support to the ship as both the bower cables do in the position N; for as N W, and N E, represent the two cables, so N S, likewise represents the amount of support in that position. It is evident that, by veering a long scope of these cables, a greater angle, and a consequent nearer approach to the strength of two cables, will be obtained; but it is necessary to observe that, by a peculiar law of mechanics, two parts of a rope which are not parallel, or two ropes connected together, as the cables are by the ship, and equally strained in the same direction as the ship strains the cables, do not possess the full strength of two parts; therefore, as the wide-spread position of the anchors renders it impossible that these cables can become parallel, even with a long scope, so the full strength of two cables under such circumstances is not attainable. In explanation of this part, it is necessary to refer again to the figure, where it will be perceived, that as N S represents the amount of support to the ship, with the cables at a certain angle, so N S would always represent the strength of a similar span at any other angle, it being the key to the question,—the measure of the force employed as well as the strength of the resisting material,—and as N E, and N W, represent the two parts of the span, N S must be less than those two parts combined, under any circumstances, however great the angle; and consequently, two parts of a rope or chain forming a span which cannot become parallel, although they may only differ from the parallel by a very few degrees, must be weaker than the full strength by the amount of that difference. This theory is capable of practical proof, and has been proved by many experiments in the testing machine.

## MAKE A FLYING MOOR.

Having prepared the ship for anchoring, overhaul and range the lee cable, and double-range the weather one, observing, however, to have the latter unbitted. Reduce sail to topsails, jib, and spanker. When near the berth of the first anchor, luff up to the wind, and let go the weather one—veer away as fast as the ship will take the cable, and stand on by the wind, being careful not to check her headway. When the range is nearly out, hard down the helm, down jib, round in the weather braces, haul out the spanker, clew up the topsails, shift the helm, and let go the anchor. Then furl sails—bring to on the weather cable, and heave in to the moorings.

NOTE.—In mooring in a roadstead, let the best anchor and cable be planted in the direction of the strongest prevalent wind, and the highest seas. In rivers or tideways, however, where a freshet may be anticipated, moor with the best bower to the *ebb*.

## TO MOOR WITH A SWIVEL.

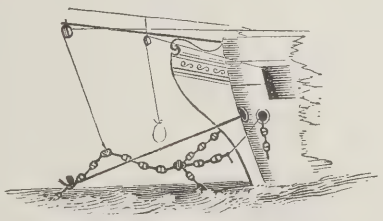
Having hove in to the necessary scope on both chains, hook the clear hawse-pendant to the slack cable, and rouse them together; (if the ship is moored with a cross.

or if she has swung a cross in the hawse, this will not be necessary.) Lash them securely, and get the pendant out of the way. Bend a stout hawser to the riding-cable, and bouse it well taut; take the swivel in the boat, and carry it under the bows; shackle the devil's-claw; unshackle the lee chain, and shackle it to the swivel —then to the riding-cable, having it so that the ship will ride by one cable, and keep the swivel clear of the cutwater. Then take off the lashing and hawser. It is necessary to keep the swivel in good order, which can be done by pouring melted tallow over it. If at any time it should not traverse, use a heaver to slue it, and clear when it starts.

## CLEARING.

In "clearing hawse," the following practice is perhaps the best, inasmuch as it embodies the general outlines of routine in the naval service.

Fig. 10.



In the performance of this operation, it is necessary to have a deck-tackle, a clear hawse-rope, (fitted with sister-hooks at one extremity,) and a pendant, called the devil's-claw. A man is then sent over the bow with a lashing, which is passed around the chains outside of the turns. If, however, the turns should extend below the surface, the deck-tackle should be clapped on the lee chain, and roused in till the turns are brought up sufficiently far to admit of the cables being lashed. After which, the devil's-claw is passed out of the *sheet* hawse-hole, and shackled to the lee cable, (if that should be the clearing one,) and then roused in taut, and secured to the bitts. Having done this, the hawse-rope is hooked to the shackle of the chain, as also a small hook-rope—the chain disengaged and eased out. When the extremity is low enough to dip, the man in the bowline unhooks, dips, and re-hooks the hawse-rope—the hook-rope in the mean time supporting the outer end of the chain, and keeping it fair at his side. This operation is of course repeated as often as may be necessary to remove the turns, and the lashing taken off at the conclusion —observing, however, to stand clear of the "jump" of the chains. If the chain should not come in readily, far enough to re-shackle after clearing, the deck-tackle may be used to rouse it in.

Note.—When a ship is moored in a tideway, with one anchor up stream (say the starboard) and the other down, she rides to a clear and not an open hawse. She would only have an open hawse when directly across the tide, provided she swung clear. If from riding by the starboard anchor at ebb tide, she swings to port, when directly across the tide she brings a cross in the hawse, being then exactly opposite to open hawse. When she has swung to the flood, she brings an elbow, nearly, which can be cleared by dipping the riding cable underneath the other, once. This is not quite an elbow, a full one being when she is across the tide, and opposite to the cross, provided at the turning of the tide she still swings foul. When she again rides to

the ebb, having swung each time to port, she brings a round-turn in the hawse nearly; but this can be cleared by dipping the riding cable once as before, and a complete round-turn after dipping the cable once, will leave a cross. She has a complete round-turn, when, at the turning of the tide, she gets into the same position as when she had a cross; and a round-turn and an elbow, when she gets where she was with a full elbow in the hawse, swinging to port each time. In clearing a round-turn and an elbow after dipping the riding cable twice, she rides to an open hawse.

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## MAN FALLING OVERBOARD AT SEA.

If *by* the wind, down helm; cut away the life-buoy; flow the head sheets, and let go the main top-bowline, main-tack and sheet, and lee main-braces, which will bring the sails aback of themselves. Haul up the mainsail by the *buntlines* only, (as the clew-garnets cannot under such circumstances be worked,) and lower the lee quarter-boat as soon as the headway is lost, and before sternway commences, observing to pass a rope's end into her from forward.* If the ship be *going free*, with studding-sails set, bring by the wind on the other tack; brace the main-yard up, and leave the head yards square. For if the main-yard be left square, it is obvious that the ship will be long coming to, will shoot further ahead, increase the distance from the man, and add materially to the delay of succor. If it be blowing fresh, however, great judgment is necessary to right the helm in time, or the ship will fly to, too much, gain stern-board, and risk the boat in *lowering*.† With regard to this point, a well-known English writer (the late Captain Basil Hall) says: "There is more mischief done generally by lowering the boat *too soon*, than by waiting till the fittest moment arrives for doing it coolly. And it cannot be too often repeated that almost the whole depends upon the self-possession of the officer-of-the-watch." The same author further adds: "If possible, the ship should not only be hove a-back when a man falls overboard, but she ought to be brought completely round on the other tack. Of course sail should be shortened in stays, and the main-yard left square. This plan implies the ship being on a wind, or from that position to having the wind not above two points abaft the beam. The great merit of such a method of proceeding is, that, if the evolution succeeds, the ship, when round, will drift right down towards the man. And although there may be some small risk in lowering the boat in stays, from the ship having at one period sternway, there will, in fact, be little time lost, if the boat be not lowered till the ship be well round, and the sternway at an end."

If the wind be directly *aft*, come to on the side on which the man has fallen; and if at night, take the bearings of the man, put a compass in the boat, and hoist a light at the peak.

* This manner of proceeding was in two separate instances practised on board the frigate "United States" in 1846, and the man saved, although the ship was going over *eight* knots at the time of the accident.

† Griffith.

## RESUSCITATION.

The following directions given by Dr. Mott, of the American Shipwreck Society, are recommended for restoring suspended animation:

"As soon as the body is removed from the water, press the chest suddenly and forcibly downward and backward, and instantly discontinue the pressure. Repeat this without intermission until a pair of common bellows can be procured; when obtained, introduce the nozzle well upon the base of the tongue. Surround the mouth with a towel or handkerchief, and close it. Direct a bystander to press firmly on the projecting part of the neck, called Adam's apple, and use the bellows actively. Then press upon the chest to expel the air from the lungs—to imitate breathing. Continue this an hour at least, unless signs of natural breathing come on. Wrap the body in warm blankets, and place it near the fire, and do every thing to preserve the natural warmth, as well as to impart artificial heat, if possible. Every thing, however, is secondary to inflating the lungs. Send for medical aid immediately. Avoid all friction until respiration shall be in some degree established."

To the above may be appropriately added the following extract from Macauley's *Medical Dictionary*:—"The measures for the recovery of drowned persons must be persevered in for a considerable time, and they must not be left to themselves when signs of reviving appear, till we are quite confident that matters are in a prosperous train. They should be put to bed, their feet being well warmed, and their shoulders raised: they should take pretty frequently, for the first few hours, some warm drink without spirits; and it will be necessary to watch lest any tendency to inflammation and fever should manifest itself, when it will be proper to bleed, according to the urgency of the symptoms."

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## JURY LIFE-PRESERVER.

The following plan of a raft for passengers and sailors, in the event of shipwreck, by the late Captain Arnold, is extracted from an old number of the "Lunarian," published in 1822:

Fig. 11.

This consists of a system of spars secured together, or a large plank, several feet in length, having a weight of some forty or fifty pounds (as ballast) attached at each extremity, on the under side; immediately over which, two large empty casks, tightly

bunged, are firmly lashed, by means of ropes passed entirely around the bilge, and in a score cut in the plank, to prevent the casks from getting loose by the force of the sea. Life-lines are then extended fore and aft on each side, as represented in the accompanying cut, and the space between the casks left clear, for the men to sit and paddle.

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2

## MAKING SAIL, (HINTS.)

In *loosing* a sail, whether it be blowing fresh or not, the *yard-arm* and outer gaskets should be cast off *first*, for otherwise the weight of the bunt would jamb them, and render cutting necessary to get them clear.

In *turning out reefs*, let go the bowlines, and settle a sufficiency of the halliards to counteract the effect of the lee leech on the weather brace, which must be rounded in enough to enable the men to get at the lee points.* If with a treble-reef, check the lee lower braces—set taut the reef-tackles and buntlines, and cast off the points from the slings, out—observing to ease the earings down together, when every point in the band is disengaged.

In *hoisting sails* from a royal to a close-reefed topsail, the *lee* brace ought invariably to be let go, and the weather one tended. As the latter is eased away, and the sail hoisted, the yard will cant of itself, till the leech is taut, which is the indication of the sail being up. If every thing is clear, there will be no necessity for hauling in the lee brace while hoisting. In setting a *jib*, the sheet should not be kept taut but eased, to let the sail go up; and observe at the conclusion, that both the stay and the guys are taut.

Preparatory to setting *studding-sails*, let the top-gallant clewline be hauled taut, that the man who goes out on the topsail-yard may have something to hold on to; and in hoisting the *lower* studding-sail, be careful that the yard is not brought up with a *jerk* against the topmast studding-sail-boom, as by the neglect of this point, the boom is often sprung. After the sail is set, the topping-lift should be slacked sufficiently to bring the outer leech taut. Where the topmast studding-sail only is carried, when blowing fresh, a toggle should be thrust into the bending-part of the lower halliards, far enough up to allow it to reach the boom on the fore-yard, the end belayed on deck somewhat aft, and the hoisting-part hauled taut to jamb the toggle.

In setting a lee top-gallant studding-sail forward of the sails, in lieu of stopping the halliards to the upper yard-arm, (which is the *outer* one,) bring them down to the lower yard-arm, so that in hoisting, the sail will capsize over, as it were, and bring the extremity, to which the halliards are stopped, uppermost. Sway higher, and let the man on the topsail-yard (when high enough) cut the stop, and cant the yard forward, which, under these circumstances, may be readily done without getting foul. If the sail should be already set, and it is desirable to "dip" it forward, lower it about halfway down—ease off the tack, and let the man on the top-

* It is unnecessary to slack the top-gallant sheets, vide page 17.

sail-yard get hold of the *outer* leech. In this way the inner yard-arm is immediately canted clear of the top-gallant bowline-bridle.

In setting either *courses* or *topsails*, in blowing weather, the rule seems to be invariable in reference to sheeting home to leeward first—the reason for which, is to prevent the sail from flapping; and if the wind is quartering, the yards should be well braced in before the sails are set.

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## SHORT'NING SAIL, (HINTS.)

In taking in a *royal* or *top-gallant-sail*, the lee sheet is started first, and clewed up to spill the sail; for in blowing fresh, if the contrary practice was adopted, the yard would probably fly fore and aft, part the brace, and risk the mast, which is of far more consequence than the sail. When the weather sheet is eased off, however, let it be done only, when the yard is clewed down.

In taking in a *topsail*, the weather sheet is started first, to prevent the sail from flapping, of which there would be danger, if it were taken in the opposite way. This rule applies equally to the *courses*, as the belly of the sail thus blows up against the stays, and is prevented from splitting. But bear in mind that the lee lower-lift should be hauled well taut before starting the tack, lest the sudden upward spring of the weather yard-arm should endanger the lee leech of the topsail; and in lieu of *letting go, ease* the bowline off handsomely with the tack.

In taking in the *jib*, if it be blowing fresh, the sheet should be slacked just sufficiently to keep the hanks from binding against the stay, which, *Gower* (an old English authority) suggests, should be slacked after the sail is hauled down, on account of the tendency to tauten, and spring the boom, from an exposure to the spray. And he further adds: "If it be required subsequently to set the sail, nothing can be easier than to set the stay up when the jib is loosing."

Previous to brailing up the *spanker*, if the weather be squally, and the ship close-hauled, the lee cross-jack brace should be rounded in a little to prevent the sail from fouling the lee yard-arm, and thereby splitting.

In taking in a *lower studding-sail*, if the wind should be fresh, the operation may be greatly facilitated by giving the ship a sufficiency of *weather* helm to "touch" the *inner* leech. The "*judicious* luff," (which Glascock quotes from a "professional writer,") under such circumstances, would in all probability be attended with the unfortunate consequences of backing the sails, and carrying away the booms. If the lower-boom should get forward under the bow, unbend the halliards from the yard, and bend them on to the boom, as far out as possible; then sway up on them and the topping-lift, haul in the after-guy, and if necessary, keep the ship off. In taking in a *top-gallant studding-sail*, always ease off the tack before starting the halliards, to spill the sail, when it may be hauled down by the sheet without difficulty.

NOTE.—In the merchant service, it is the practice to keep the top-gallant yards aloft during all weathers, and under all circumstances, at sea. This is done to in-

crease (so to speak) the amount of top-hamper, and prevent the ship from rolling; and the argument used in support of the practice is, that a ship should always be so sparred as to carry them, for if not, she is *over-sparred*. If this be true, (and so it would seem,) the spars of men-of-war are too heavy in proportion to their hulls, and the *mast-heads* too *short* to support them sufficiently.

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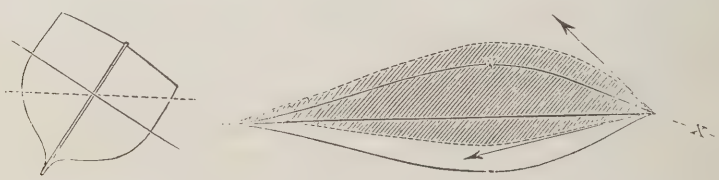
## SQUALLS.

The only question of importance involved in the whole subject of an officer's conduct in charge of a ship during a squall, when by the wind, is, *must he luff*, or *must he keep away?* If the daily practice of the merchant service be any criterion; if the opinions of skilful seamen may be considered as having any weight in the matter; and lastly, if the declarations of reason and common sense affect the question in the smallest degree, a ship should *never* be kept off when sailing close-hauled to the wind. In the first place, the natural tendency of the vessel is to luff of herself, when careening under her canvas, and so great indeed is this disposition, that it requires a powerful effort of the helm to counteract it. This may be shown by an exceedingly simple diagram, thus:

Fig. 12.



Here, it will be seen, that when the vessel heels to either side, the shape of her displacement is entirely changed, and consequently the *resistance* upon the bow unequally divided—that to leeward being greater than its opposite, in the ratio of the ship's inclination. Under these circumstances, it is manifest that the ship will be forced in the direction of the dotted line x, or in other words, *luff* of her own accord, and without any action of the helm whatever; while at the same time she approaches the wind, which soon loses its effect upon her sails. Again, if the ship be kept away, sail cannot be shortened until the wind is abaft the beam, and to reach which, she must pass some point, where its whole force will be exerted to overset her. But independent of this consideration, (which by-the-by, is a most material one,) a ship loses ground by running off, and there are often circumstances which render it both impolitic and unsafe to do so.

The argument employed by the opponents of the *practice* of luffing, is the liability to get aback, and the consequent danger to be incurred by making a stern-board. This, however, is readily refuted, if we consider but a single moment the effect of the vessel's form upon the water; for it is plain, that when she careens over, the shape of displacement *aft* is changed as well as forward, and therefore the *resisting*

surface of the lee side is greater than that to windward. Hence, when the ship has a sternway motion, and also an inclination to leeward, it is almost *impossible* to force the stern in that direction.* From this, it is easy to see that the bow will pay off almost immediately, when the sails will either shake or again be *filled*.. But it may be said in continuation of the argument, "a ship does not always incline to the lee side when aback." Granted: all know the effect of the rudder, and if it be *a-lee*, (as we may suppose,) the question whether the ship will fall off now or not, answers itself. In luffing to a squall, however, let it be done with a steady helm, and be quick to meet the ship when she "trembles." And here arises a point in trimming the yards in squally weather, to which it is perhaps well to refer—viz. the after yards should *always* be trimmed "fine," or in other words braced in sufficiently to touch their sails when luffing, while at the same time the head yards stand *full*. This, at all events, is the practice of the merchant service—a practice which has withstood the infallible test of successful application for years and years of boisterous servitude.

NOTE.—Lastly, never trust a squall which you cannot see through, for when a heavy squall strikes you, you can seldom reduce sail without losing it.

## BAROMETRICAL INDICATIONS.

The following observations are abridged from the "Popular View of Meteorology, and its Practical Uses to the Seaman," by Captain William H. Smyth, R. N., F. R. S., &c.

It is not the absolute *place* of the mercury which must be consulted; but the convexity, level, or concavity of surface, as indicating a disposition to rise, remain stationary, or fall; and the time when such disposition commenced. The relative situation of the sun must also be considered, as well as the height of the thermometer, though the bracing or relaxing power of the atmosphere, by the forces of expansion and pressure on the leathern reservoir, far surpasses any effect of heat on the quicksilver. Owing to these circumstances, a few general rules for interpreting the movements of the barometer may prove acceptable to beginners, especially as the words engraven on the side-plates rather mislead than instruct; since the true scale will be found also, in some measure, to depend on the season of the year, and the latitudes, as well as height, of the place of observation.

From various experiments, the mean pressure of the atmosphere at the level of the sea is estimated at about thirty inches; and, for common purposes, a tenth of an inch depression may be allowed for every eighty feet of additional elevation.

The deviations of the mercury *without* the tropics are greater than those within them; and are there greater and more frequent in the winter than in the summer. But though slight changes are scarcely shown near the *equator*, and heavy squalls may occur without being anticipated, yet the approach of á hurricane is foretold by the usual fall of an inch or more. In calm weather, with inclination to rain, the mercury is commonly low and sluggish. It sinks lowest, everywhere, to extremely

* An evidence of this occurs in the backing of a steamer, where (if she careens at all) it is impossible to force her stern to *leeward*, by reason of the unequal pressures upon the after body of the vessel.

violent winds, which may be accompanied by rain; yet it rises to northeast and east winds, during which there may also be showers without any intimation from the quicksilver. When it sinks with the wind in those quarters, an alteration will take place.

If the barometer has risen during the night, and is still rising, with the hygrometer decreasing, the clouds high, and wind moderate, particularly if it be from the north or east points, a dry day may be confidently expected. The same rule applies from evening until morning. Indications for foul days and nights will obviously be the reverse.

Although the rising of the mercury, *cæteris paribus*, is held to presage fair weather, and its falling, especially with an increase in the hygrometer, the reverse, yet it should be noticed, that a sudden rise may sometimes indicate a southerly wind, which often brings rain; but in winter it portends frost; for the quicksilver, from palpable causes, is wont to be higher in *cold* weather than in warm. It must also be remembered that the daily maximum of the barometer is usually about nine o'clock in the morning, the mean at noon, and the minimum at three P. M. When the elevation or depression is rapid, the consequent change will be of short continuance; but slow and progressive variations indicate permanency.

In winter, spring, and autumn, the sudden falling of the mercury denotes hard gales; but in summer, heavy showers and thunder. From the greater variations of the quicksilver between October and April, it follows, that the fall of one-tenth of an inch in summer is as sure an indication of rain as two or three tenths in the winter. Thunder may happen without sensibly affecting the barometer; but in this case the storm seldom reaches far; and when it is attended by a fall in the tube, its effects will be found to have been more extensive. If the quicksilver falls very low, although the weather continues mild and moderate, it is the effect of a contemporaneous gale in some distant place. These apparent anomalies account for the charges occasionally made against barometers of giving false alarms.

In the English Channel, off the Azores, and along the Atlantic shores of France, Spain, and Portugal, the writer has had repeated proofs of the unerring efficacy of the marine barometer.

Between the capes of St. Vincent and Spartel, the southwest winds are the most disagreeable; but the depression of the quicksilver is sure to denote a violent gale. A gale in this quarter is always precursed by a long hollow swell from the westward.

Within the Mediterranean, the predominant breezes are from the north and west quarters, except in the spring, when southeast and south winds prevail; but their duration and strength are extremely uncertain about the period of the equinoxes. As the barometer does not generally vary more than a few lines, it requires great attention to mark its indications: they will, nevertheless, prove satisfactory; and it may be laid down as a general rule, that whenever the quicksilver sinks so low as 29° 40′, a *severe gale* may be expected.

In the eastern division of the Mediterranean Sea, the north winds are mostly dry and salubrious, though cold and often violent, while the south one is mild and moist, accompanied by rain; that from the east is laden with mist and vapor, and the western, though often stormy, produces clear skies and exhilarating effects. The nature of these winds differs essentially according to locality, but they never blow very violently without a corresponding effect upon the mercury.

The most annoying wind is the *sirocco.** At its commencement the air is dense and hazy, with long, white clouds setting a little below the summit of the mountains, and at sea, floating just above the horizon, in a direction parallel to it. The thermometer does not at first experience a very sensible change, though it rises with a continuance of this wind to 90°, and sometimes to 95° ; the barometer gradually sinks to 29° 60′.

In the Adriatic, the weather is notoriously mutable : calms, thunder, and waterspouts being frequent all the summer; and heavy northerly blasts, called boras, with fogs and hard squalls, during the winter. The bora† is greatly dreaded in the upper part of the Gulf of Venice, particularly in the channels of the Quarnero, where it rushes down the whole line of the Julian Alps with irresistible fury. The coming of this wind may be known some hours beforehand, by dense cloud-banks on the horizon, with light fleecy clouds above it, and the sky rather lurid. Its general direction is from north to northeast, and its continuance about fifteen or twenty hours, with heavy squalls, and terrible thunder, lightning, and rain at intervals. These winds, however, give sufficient notice of their approach to an attentive observer, although violent squalls of short duration may be encountered without much barometrical indication.

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## MISCELLANEOUS HINTS.

### LYING TO IN A GALE.

As a general rule, the *main-topsail,* close-reefed, is the best—as any other sail would, in all probability, be becalmed. Sometimes the fore-topmast staysail is used to great advantage, especially if the mainmast be far aft. The helm should be kept about halfway down, but after sail should never be set to make the ship lay higher, as it brings her so close to the wind that she loses her headway, and is then knocked off by the sea, until she brings the wind far enough abaft to gather headway again ; whereby a constant falling off and coming to is maintained. The forward and after yards should be pointed to the wind, and the main braced sharp up, with the yard clear of the cap, as the sail by being flat is not so apt to shake ; and if the ship should forge ahead too much, which will probably be the case in a sharp vessel, back the head yards.

* The sirocco generally continues three or four days, during which period, such is its influence, that wine cannot be fined, or meat effectually salted ; and oil paint laid on whilst it continues, will seldom harden. During a sirocco, the Maltese *refuse* physic.

† Ships caught by the bora generally let fly every thing to receive the first blast, and immediately bear up to the southward to seek safety in any port they can fetch, or remain under bare poles until it is exhausted. Many prizes during the war were lost by violent gusts, and some of our cruisers have been nearly laid on their beam-ends when caught unawares. In December, 1811, the French frigate Flora, of 44 guns and 340 men, was surprised by a bora, on her passage from Trieste to Venice, which threw her on the coast near Chiozza, where the captain and two-thirds of the crew perished ; and, in 1820, the Montacuculi, an Austrian corvette, was met by one, while under all sail, and instantly foundered with all hands.

NOTE.—In the fitting of the California steamships, Capt. Skiddy had prepared for each vessel a *parachute drag*, made of iron, which was covered with canvas, and opened with hinged arms like an umbrella. At the inner end of the central beam a stout ring was made for the purpose of bending a hawser, and at the outer end a similar one (but smaller) for a hauling line. This was to be employed in the event of heaving to, as by veering out forty or fifty fathoms of the hawser, on the drag, to windward, and belaying it to the bitts, the head of the vessel is kept up to the wind and sea without difficulty. If the vessel should afterwards have a tendency to pay off, veer out more.

In the merchant service, where a vessel sometimes lays to badly, I have heard of the fore-top-gallant-yard being spanned and used as a drag to windward.

## HEAVING-TO, TO COMMUNICATE.

When heaving-to, to communicate with another vessel at sea, it is advisable that the *windward* ship should lay with the *fore*-topsail to the mast. The reason for which is, that she will fall off, and come-to less, under this arrangement of her canvas than otherwise,* which arises from the extent of sail-surface exposed to the wind, to assist in keeping her to; while the forward sails, by being smaller in proportion, are more readily filled, in the event of having to shoot ahead. If to leeward, with the *main*-topsail to the mast, it is only necessary to shiver the mizen-topsail, shift the helm, and fall off.

## ROPE FUNNEL.

In the absence of a proper funnel in watering ship, one may be constructed of rope, by taking a piece of small stuff of sufficient length, and flemishing it down as neatly as possible, at the same time binding the parts closely together, with rope-yarn stops at each turn. When the flemish is large enough, or as near the size as required, turn it inside out, so as to form a conical shape.

## RECIPE FOR TARPAULIN COATS.

Boil one gallon of linseed oil, until the heat of it is sufficient to scorch a feather; then add $\frac{1}{2}$ lb. of dry red lead: while boiling, add also $\frac{1}{2}$ lb. of litharge, and when cooling, a sufficient quantity of best mixed black paint, to give it a color. Give the cloth one light coat previous to cutting out, and two or three afterwards when made up—having a stump brush to put it on.

* An illustration of this fact is seen in the case of whale-ships, which are often hove-to a greater part of the time, with the fore-topsail to the mast, when engaged in the operation of "cutting out."

# STOWAGE.

# PART III.

## STOWAGE.

### INTRODUCTION.

In tracing the history of the various branches of the nautical profession—a history which is rather traditionary than otherwise—the question often arises among its members (and as yet none have attempted to give a solution) as to when, and where, and how, and under what circumstances, *stowage* became not only a distinct department by itself, but subsequently indeed, a separate profession; and which is now-a-days exclusively a shore occupation, and in many instances followed by men who have never been at sea. To obtain a satisfactory answer to this question, it is only necessary, I opine, to consider, that within the last quarter of a century, the attention of nautical men has been directed to an elucidation of the theories of floating bodies —of the resistance of fluids, the pressure of the atmosphere, and the action of wind upon sails—the estimation of capacity, of gravity, and of tonnage, and latterly, of the principles of naval architecture, and to the consideration and application of steam, —circumstances which have rendered *seamanship* (giving it the broadest acceptation) rather a *science* than a rude and humble occupation for men—a science outvying all others in the immensity of its details, and the infinity of its limits; and as such, *necessarily* beyond the feeble grasp and comprehension of individual faculties. Hence the heterogeneous division of constructors, engine-builders, navigators, sailors, and *stevedores*. But again the inquiry suggests itself, and we are called upon to account for the fact, that while our libraries are replete with works upon naval architecture, and steam, and navigation, and seamanship, we may search in vain for a treatise on *stowage;* and if it be true, that "the most trivial variation in the disposition of the weight with which a vessel is charged, has been known to effect a material variation in her stability, floatation, and velocity;" and also, that the subject is conceded by professional writers to be of "the most paramount naval importance," one cannot but be struck with the long and shameful neglect which it has been suffered to experience. The reason, however, is obvious: when we consider that as the science of seamanship merged from its primitive obscurity, and became identified with the history of commerce, the attention of nautical men was directed to the (apparently) more learned and respectable branches, while that of stowage was abandoned almost entirely to the care of men, who, tired of the sea, and incapable of scientific attainments, (or indeed of a written treatise,) adopted it as a means of

living. Nevertheless, attempts have been made by professional writers to "pluck out the heart of the mystery," and impart such a knowledge of it as might serve the general ends of practical men; but the absence of first principles, and the neglect to consult the lowly practitioners of the branch, naturally enough produced a failure for these authors, and enveloped their readers in an impenetrable *fog* of ambiguous terms and pseudo laws.

Glascock, who enters more at length into this subject than writers in general, says: "To achieve something like a successful stowage, it is highly essential that the stower be thoroughly acquainted with the vessel's construction, capacity, trim, 'recorded qualities,'* and, above all, the *builder's* 'centre of gravity of displacement,' bearing in mind that due consideration be given to the several contending conditions involved." Beyond this, however, he does not go, (notwithstanding the admitted excellency of his work,) and while he fails to tell us the meaning of these isolated and *mysterious* terms, his own pen rises up in judgment against him, as it were, and he devotes the balance of the article rather to a display of his knowledge as a *critique*, than as a professional *stower*, thus:—"One writer after losing himself in a labyrinth of complicated cases, involving a series of nautical conditions too deep for his fresh-water knowledge, winds up *his* scientific paper in the following *satisfactory* strain:—'These principles [mark, *principles!*] *govern* the stowage of ships; the manner and degree by which they must be carried into *practice* must be *ascertained* by *experiment.*'" Verily, as Glascock says himself, "it is productions of this stamp that bring science into disrepute." So far as the author of the *Manual* went, in his analysis of stowage, he was correct enough; and we shall content ourselves with writing the sequel of his "narrative," by giving, first, in a condensed article, the general outlines of construction, together with a few "Yankee notions" of modelling, for the purpose of aiding practical men "to achieve something like a *successful* stowage."

The views which are comprised in the first portion of this subject are gathered entirely from conversations with Captain Wm. Skiddy of New York, whose well-earned reputation and acknowledged skill, both as a constructor and a practical seaman, render, I apprehend, all comment upon the merits of the article unnecessary and superfluous.

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## CONSTRUCTION.

The following brief analysis of the guiding rules of construction will be found sufficient for a sailor's stock of knowledge.

Let us consider, first, what constitutes a good model for a sailing vessel, or in other words, one which combines the essential requisites of *safety*, *capacity*, and *speed*.

1. In order to attain *safety* it is necessary to have *buoyancy*; and to have buoy-

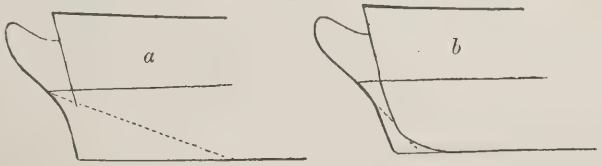
* The term "recorded qualities" manifestly refers to vessels which have been at sea; and if the difficulty of obtaining this species of "documentary evidence" were properly estimated, it would be found in most cases to exceed the absolute value, and something over.

ancy the vessel must have length, and experiment has demonstrated that this should only vary between *four* and *five* times the *breadth* of *beam*. For if we exceed the maximum limit, we sacrifice *strength*, (which is one of the material elements of safety,) and render the lateral movements of the vessel tardy, on account of the length of the arc she inscribes in the performance of the evolutions of tacking and wearing. On the contrary, if we diminish the length below the minimum, (still preserving the breadth,) we again lessen the powers of speed, by rendering the vessel bluff and clumsy, whether we regard her of rectangular or circular form. For it must be borne in mind that when we combine length and breadth, we have necessarily, then, to consider shape, and upon the relative proportions of which, as we shall see, depend almost entirely the safety, capacity, and speed of our future ship.

2. To have *capacity*, the vessel must have *depth*, for otherwise she would be only a surface; and again, experiment has prescribed the limits which guide and govern its application—viz. that it should never be less than *one-half* the breadth of beam, nor more than *two-thirds*: because in the first case we destroy *buoyancy* and the capacity for cargo, by an excess of shallowness, whereby we cause the vessel to be stiff and laborsome, and to counteract which, strength, an utter impossibility under these circumstances of length and depth, is absolutely essential. In the other case, on the contrary, the centre of gravity is so much elevated above the line of floatation, that the vessel becomes altogether too unstable to answer the conditions of safety. Hence, we perceive the force and deduction of this rule—a rule which becomes infinitely simple, so far as the matter of *dimensions* is concerned, when we have once established the beam of our embryo bark.

3. And last, but not least of these important considerations is *speed*. This is attained by constructing the bow, bottom, and stern in such a manner as to cleave the water with the least effort, and at the same time assist its aftward transit. In shaping the *stem* it is usual to give it a very slight rake of not more than one foot to every three feet of depth, in order to render the vessel buoyant forward, and lift her in plunging, which would only be the case after a portion of the sea had boarded her, if the stem were made to rake any considerable quantity. The *bow* should be made sufficiently sharp to *cut*, not bruise the water; and the more *wedge*-like we form it (consistent with strength—for we cannot lose sight of first principles) the nearer the aftward course of the water will approach to a horizontal line, and the smaller will be its angle of resistance. This may be illustrated by a very simple diagram, thus:

Fig. 1.




In the foregoing figure, *a* represents the bow of a sharp ship, and *b* that of a bluff one, wherein the dotted lines indicate the course of the water, which is more or less inclined to the horizon, as its passage is impeded by the shape of the bow.

But let us see how far these principles are consistent with the acknowledged views of scientific men. Booth, in treating of the "*Theory and Practice of Propelling through Water*," says: "When a body moves through water, the pressure of

the water on its sides constitutes *friction*, and forms part of the resistance to be overcome; and there seems no reason why the law which regulates the amount of this resistance should differ from the general law regarding friction—viz. that it is the same at all velocities. In calculating the power required to move bodies on a railway, we consider the friction as a fixed quantity, and then allow for adventitious causes of resistance, as the opposition of the wind, concussion from vibration, &c., which vary with the speed or other causes. When we attempt to estimate the *quantum* of resistance which a body will meet with in moving through water, we ought to adopt a similar course of analysis. The constant resistance is friction. First, the friction between the water and the sides and the bottom of the vessel; and, second, the friction between the particles of water themselves displaced by the *bow* of the vessel, and closing in behind as the vessel proceeds. Resistance from this friction proper is the same at all velocities. But there are other forces to be overcome which vary *with* the velocity; and these are principally—gravity, and the pneumatic resistance. The amount of these two opposing forces depends on the *form* of the vessel. By gravity is meant the resistance occasioned by raising up the water in front of the vessel, and which takes place when a vessel is very full-built *forward*—the consequence of which is, the vessel labors against *a hill of waters*. * * * Both these varieties of resistance are distinct from the unavoidable and necessary resistance of a body passing *through water*, and which is said to increase in a fourfold ratio with every increase of *speed*. We can easily conceive a body, as for instance a thin board placed edgewise in the water, with its two ends fore and aft sharpened to a knife's edge. To draw this body through the water would require a given power, at any velocity named, and the resistance being almost entirely *friction*, it would, as friction on a railway, be nearly the same at all velocities—the increase of power required being simply *as* the increase of speed."

At the midship section, or point of greatest breadth, (which should be *forward* of the centre,*) the *floor* should have a "dead rise," as it is technically termed, of about 10°—or, since a vessel seldom *heels* more in the ordinary circumstances of sailing, an inclination upward, equal to the angle her deck would form with the horizon, in careening under a pressure of sail. The object of which is, that when the vessel lays over thus, she rests upon a flat floor, against which, the water (acting at right angles) exerts its greatest upward pressure to right her; while at the same time it operates upon the keel, and prevents the vessel from sliding to leeward—a consideration of no little magnitude in sailing by the wind. If, on the contrary, the vessel be constructed with a flat bottom, or floor, she will be less stable than one in which the dead rise is greater; and in careening, all that portion of water contained between the bilge and the lower part of the keel will (in consequence of the deeper immersion of the former) be filled with eddies, which exert no pressure whatever, to prevent the vessel from "sagging" to leeward.

The *length* of the floor depends less upon fixed principles of construction than the attention which is paid to the consideration of *sharpness;* and it is plain, under these circumstances, that the longer the ship, the longer the floor. Hence it is, that no rule can be laid down which will be applicable to all the conditions of practice: although many builders extend the floor beyond the usual limits by keeping the ship

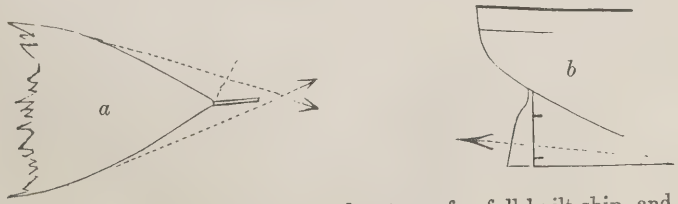
* The reason is obvious—for it is only necessary to consider the constant action of the sails in pressing the bow down to the sea; and to resist which, the predominant portion of *buoyancy* must be forward of the centre.

*full* below; by which a greater amount of *capacity* is obtained; but it is highly questionable if there is not, at the same time, a corresponding loss of *speed*. Moreover, by having an increase of *buoyancy* below the line of floatation, the body of the vessel will be more elevated, and as a necessary consequence she will possess less stability than before.

Another important feature in construction is the shape of the *sides* above the water-line, inasmuch as it involves, to a certain extent, the considerations of *strength* and *stability*. If the vessel be "wall-sided," (as it is vulgarly termed,) it is evident that in careening under her canvas, or otherwise, all the weight on the *lee* side, above the proper bearings, will project beyond the base of the floor; while at the same time the *outward* pressure of this portion of the cargo must be sustained by the top-frame. In men-of-war, and vessels which carry heavy weights upon the spar deck, this becomes of paramount importance. If (to take the reverse of this principle) the sides be made to "tumble home," or to "swell," as it is technically called, the weight of the cargo will seldom extend beyond the bearings of the ship, and the downward tendency will be communicated through the frame timbers to those of the floor, against which, as we have seen, (if it be properly constructed,) the reactive pressure of the water is at right angles, or forming "one and the same straight line" with the direction of the gravitating force. Again, so far as the question of mere *strength* is concerned, it is evident, that the more arch-like we form the sides of a vessel, the greater amount of pressure they will sustain; but however necessary the attainment of strength and stability may be, we have also to consider the importance of *capacity*. Experiment therefore has established, as a general rule, that the tumbling home, or swell of the sides, should not exceed an inch to the foot of depth of hold.

In reference to the shape of the after-body, care must be taken that the *counter* be sufficiently high, and the *run* clear, in order to diminish as much as possible the "pneumatic resistance." This is defined by Booth, as "the resistance occasioned by a vessel being very full and clumsily built *abaft*;" and he further adds, "When a vessel is round, or square-built behind, however sharp before, if it be attempted to move fast, there is not time for the water to close in, and the consequence is, a tendency to a partial vacuum; or what is vulgarly called *suction*, takes place—or a drawing of the water in an *eddy* after the vessel, instead of the vessel passing smoothly *through it*, which is the case where there is a fine clear rake behind." Indeed, where the counters are deep, and the buttocks heavy, the course of the water, in its escape from the bottom, is *flattened*, as it were, and full of eddies—a result which is highly detrimental to the *steerage* of the ship; first, by precluding the access of the water to the rudder, and, second, by bringing the entire strain upon the *heel*. This may be demonstrated thus:—

Fig. 2.

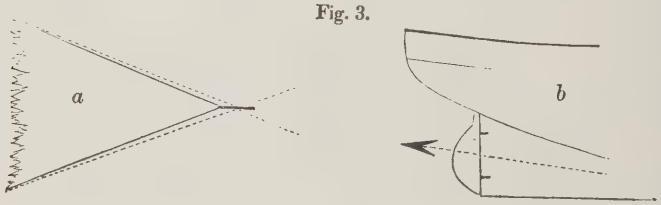



In the foregoing diagram *a* represents the stern of a full-built ship, and the dotted line the course of the water. We perceive here, that the rudder is scarcely

touched by the passing fluid, and if so, only by an eddy *current*, which rather offers a *negative* than positive resistance, by flying off, when brought in contact with the rudder. Again, *b* will serve to illustrate a *side* view of the same stern, where the aftward course of the water is indicated by the dotted arrow, which, from the fulness of the counter, is rendered nearly *horizontal*—while the *heel* of the rudder is the only part (if any at all) which sustains the pressure.

The converse of these effects may be illustrated by a diagram similar to the following—wherein we perceive that while the sharpness of the bottom abaft permits a free access of the water to the rudder, the course of the passing current is *less* horizontal than in the previous case, and at the same time the point of resistance on the rudder, in lieu of being at the heel, is more *central*—hence we see the necessity for having the broadest part near the middle, and the reason why (now-a-days) the heel is often rounded, particularly in vessels with a fine clear run.

Fig. 3.




A series of experiments, in rounding the heel of the rudder, was made many years ago on board of some French frigates at Brest, and the result proved entirely satisfactory, particularly in those vessels with high counters and clear runs. Subsequently this feature in construction was introduced in this country by Capt. Skiddy; and within a recent period many ships have been fitted in this manner. During a heavy gale in the winter of 1829, the packet ship "Henry IV." lost her rudder; and it became necessary to construct a temporary one, in order to get the vessel into port. But, in consequence of the want of proper and sufficient materials, the captain was obliged to form a rudder, which only extended about halfway down the sternpost. This, however, answered the purpose even better than the original, and the ship steered with far less difficulty than before. Other instances might be cited in proof of the principle in point, but the above is deemed sufficient evidence to substantiate the truth of what we have advanced.

Again, with regard to the formation of the after-body of the vessel, it must be borne in mind that the same reasoning applies to the position of the *sternpost* as to the stem, viz. that it should rake (*if at all*) but a trifling quantity. Indeed, when we reflect, that the predominant portion of *buoyancy* is forward, and that the tendency of the vessel is to sink deeper abaft, attention to this feature in the build becomes obviously essential.

It is not the design of this work (nor is it deemed necessary to the subject of stowage) to enter into all the minute details of naval architecture. Sufficient has doubtless been said in the foregoing pages (by way of elementary principles) to serve the ends of practical and professional men. Nevertheless, there is one more point to which it is perhaps well to call the reader's attention, and which is introduced here more for the want of an appropriate place elsewhere in the book, than from any relation it has to the subject of stowage.

Within a recent period it has been discovered, that in consequence of the number

and use of *iron* bolts and fastenings in the upper works of vessels, *abaft*, the compass has suffered a very considerable degree of "local attraction," and to obviate which, (in some measure,) it is proposed to use *copper* bolts, within a circle of certain diameter, having the binnacle for a centre.*

The existence of this attraction, and its influence upon the variation of the compass, is so clearly expressed in a series of contributions to the "*Nautical Magazine*," by Mr. W. Walker, Master, R. N., that I take the liberty of giving a condensed view of the subject, in the language of the writer:—

In order to show how iron may, by its inductive property, either control, or be controlled, by a steering-compass, let one be placed anywhere out of the influence of masses of iron. Take any number of pieces of iron of different sizes, from a small nail up to a large spike or bolt. Now experiment has proved that these nails are each inductively magnetic from the earth by position. Take a small nail and hold it vertically near the north point of the compass, the lower end of the nail being at the same height as the compass-needle. The nail, instead of repelling, will attract the north point, because the needle converts the nail, for the time being, into an inductive magnet, and controls the earth's inductive magnetism. Change the small nail for a larger, and as you increase the size, you will at last find a certain sized piece of iron that will control the compass-needle, by the induced magnetism received from the earth. Hence we infer that although each and every piece of soft malleable iron is magnetic by induction from the earth, yet the quantity of magnetism which the earth imparts to a small nail, may be cancelled and controlled by a magnetic compass-needle, although the natural quantity of magnetism which the earth may communicate to a larger portion of iron may control the compass-needle, and either attract or repel it, according to its position with reference to the direction of the magnetic *dip*, and the poles of the needle.

If an iron bar be placed in an east and west direction from the centre of a compass-needle, and in a horizontal position, it will not disturb the compass, nor will the needle be affected by it; but a rod or wire so placed will conduct inductive magnetism to the compass. This is an important fact, because great magnetic energy may arise and influence a steering compass, from arrangement of the iron in a vessel. If, for example, a merchant vessel had a cargo of iron in her hold, or even iron tanks, steam-boilers, or cylinders, so stowed as to be in contact with an iron knee, or iron truss bolted to the ship's side, and running upwards to the upper deck beams, such a piece of iron being in contact with large masses of metal in the hold, would *conduct* or transfer the magnetism from below, and would certainly derange the magnetic needle, and cause the compass to indicate a wrong course!

It is on this principle of magnetic conduction, that separate pieces of iron when brought in actual contact, act magnetically as a single mass. The water-tanks in a ship-of-war, if stowed in actual *contact*, will act on the compass, as if a single tank of the same size as the aggregate number of small ones in the hold occupied their places. But if the tanks be kept separate by thin slices of board, then each separate tank, &c., will retain its natural quantity of inducting magnetism, and the place of its *poles* will change with the motion of the ship.

Everybody who has been much at sea, or who has been in the habit of watching the motion of the compass, must have observed that the card does not remain very steady in its bowl during bad weather; when the ship *lurches* heavily, or rolls from side to side, the compass-card oscillates several points from the actual direction of the ship's keel: when a ship is running before the wind in a high sea, and rolling, perhaps, 15° or 20° on each side of the perpendicular, her compass-card may swim, or vibrate a *couple of points* on each side of the course! To remedy this oscillation of the compass-card, weight is added in the shape of wax,

* Through the instrumentality of Capt. Skiddy, this precaution was adopted in the construction of the steamers "Panama," "Oregon," and "California," and in the new packet ship "Constellation," vessels built under his superintendence; and doubtless, ere long, the importance of this feature will become manifest to every builder.

brass bars, &c., for it has been considered that this vibration arose from mechanical action. There is, however, no 'law of mechanics' whereby this action can be satisfactorily explained.

We have already explained how the poles of a piece of iron are to be found by means of the magnetic dip. Now the magnetic dip has reference to the earth, and *not* to a ship, and the iron she may contain. We may, for our present purpose, regard the earth as a fixture, but a ship when afloat and at sea is a moveable body, changing her position and direction; inclining by the force of the wind on her sails, or rolling and pitching about by the action of the waves on her hull. Now the magnetic dip of the needle, and the consequent magnetic polarity of the iron that a vessel may contain, is always referable to a plumb-line, (because we measure the dip from a vertical;) consequently the ship and her contents are constantly changing their relative positions to the dip, and also to the magnetic attractions and repulsions which every article of iron that the vessel may contain receives by induction from the earth. Whenever a ship changes her position or her inclination, a new magnetic force is brought to bear upon the compass; and when the ship rolls alternately from side to side, equal and opposite magnetic forces act upon the compass-needle, and cause it to oscillate on each side of the true magnetic direction of the ship's keel. Now let us suppose that there is an iron gun on each side of a ship's quarter-deck, and exactly abreast of the binnacle. When the ship's head is either north or south, the guns will be in an east and west direction, and so long as the ship *remains quite upright*, they will not derange the compass-needle. But let the vessel be inclined, the magnetic polarity of the two guns, and also of every bolt, bar, or nail that may be fastened through the sides of the vessel, will have changed its place in the iron. Let the direction of the ship's head be north, and her inclination be to starboard, then the breech of the *lee* gun will attract the north point of the needle, and its muzzle will attract the south point.

On the other side of the ship, the breech of the weather gun will attract the south point of the needle, and repel the north point of the compass, so that the north point of the compass-card will be drawn to leeward by the lee gun, and driven in that direction by the weather one, whilst the south point of the needle is drawn to windward by the weather gun, and driven to windward also by the lee gun. If the water be smooth, and the ship's inclination be permanent, this kind of local attraction will permanently derange the ship's course; but if she roll from side to side, the compass-card will also vibrate on each side of the course. If the ship's head be north, (as before,) but her inclination to *port*, by a strong easterly wind, the polarity of the guns will be inverted: that is to say, the *lee* gun now will attract the north point of the compass-needle, and draw it towards the lee side of the ship; and the weather gun will repel the north point, and attract the south end of the compass-needle. In this way the compass, instead of indicating a course of north, may show a N. $\frac{1}{2}$ E., or a N. by E. course, in smooth water, and in north magnetic dip, but should the vessel be running before the wind, and rolling heavily from side to side, so that at every roll of the vessel, the inductive polarity of the iron within her is actually transferred from one side to the other, the compass-card must necessarily go on in an endless oscillation, unless means be devised to prevent it. The ordinary means resorted to by seamen, is to increase the weight of the card; that is to say, to use a more sluggish instrument.

It was owing to the vibratory motion of compass-cards mounted in wooden bowls, that brass bowls were substituted for the wooden one. The fact is, that copper or brass is capable of receiving an inductive magnetism from a magnetic needle near it; and although a brass-bowled compass may not vibrate like a wooden-bowled compass, it is beyond a doubt, that a card mounted in a brass bowl is more sluggish in fine weather. It is even frequently necessary to have small lines attached to what are called heavy compasses, in order that the helmsman or quarter-master may agitate the compass, and cause it to traverse in light winds and smooth water. The means therefore that have hitherto been adopted by seamen as well as by the makers of ships' compasses, have not been founded on sound principles. These oscillations were supposed to arise from some principles in mechanics not easily understood: whereas the vibration of the needle arises from a change of place in the magnetic poles of the iron, and other things that enter into the construction of the vessel and her contents: and it will be

shown hereafter how these vibrations, and in fact the local attraction generally, may be rectified and got rid of.

But in order to convince seamen that the oscillation of their compass arises from magnetic action, the following experiments may be made in any vessel: Place a short plank (in equilibrium) upon any thing, so that it may rock or roll from side to side, like the rolling of a ship. Place a compass upon its middle, the plank being in an east and west direction; and it will be found that the compass-card *will not vibrate*, although the plank may be moved, or heeled from side to side. Place now a large bolt or bar of iron on each side of the compass, and it will be seen that the compass-card will swing or vibrate, if motion be given to the plank.

The experiments we have been explaining *prove* beyond any doubt that iron is magnetic, that it has magnetic poles, and that these poles are always referable to the direction of the dip of the magnetic needle, and *do not* remain in a permanent position in the iron. Any attempt that may be made to correct the local attraction of a ship's compass, or the oscillation of the needle in stormy weather, must necessarily fail unless the operator understands clearly the philosophy of his subject. * * * In iron-built vessels, the compass must always be liable to great derangement and irregularity, and less dependence should be put upon their dead reckoning. In ships built generally of timber, the local attraction upon the compass presents nearly a uniform character, although the amount of deviation may vary in different ships and with different *cargoes*. The rudder is fixed at the stern, the steering wheel is near the rudder, and upon the upper deck; consequently the compass must be placed near the helmsman; that is, upon the upper deck, and near the after end of the vessel. The principal quantity of iron in a ship will therefore be before and below the compass, and the nearest inductive magnetic poles in the iron will act more powerfully on the compass than the more distant and opposite poles. The result is, that in our hemisphere, the north point is drawn *forward*, and in south magnetic latitude, it is the south point of the compass that is drawn forward by the ship's local attraction, and the greatest effect takes place when the ship's head is nearly east or west.

The amount of attraction or repulsion of iron upon a ship's compass, will depend upon the quantity, mass, or magnitude of the metal, and its distance from the compass-needle. The disturbing magnetic action of the iron increases as its distance from the compass diminishes, in the inverse duplicate ratio of the distance; that is to say, if we place an iron bar at four feet from the compass-needle, its magnetic action will only amount to one-fourth of what it would be at two feet, and one-sixteenth of what its force would be at one foot distant, and so on—the force increasing in the inverse duplicate proportion of the distance. We see, then, that a small quantity of iron, as an iron bolt in the corner of a hatchway, or skylight, if near the binnacle, may act upon the compass as powerfully as a gun would act, when secured in a port at the side of the ship. The derangement of a compass, by the magnetic action of masses of iron, may be ascertained at sea by its oscillation, and by its indicating different bearings of a distant object when the ship's head is in different directions at the same anchorage. Another sign of the existence of local attraction in a ship at sea is noticed when beating to windward, say with a northerly wind, when the ship appears by the compass to lie within *four* or *five* points of the wind; whereas when beating to the southward, she may appear to be no closer to the wind than six or seven points. These anomalous appearances in the direction of the ship's head arise from the north point of the compass-card being drawn forward on both tacks by the local magnetism of the vessel. Whenever these symptoms appear, a compass should be placed on the forecastle of the ship, and the magnetic direction of the ship's head on both compasses noted. The one in the binnacle will have its north point drawn forward, and the compass forward will have its north point drawn aft. Hence the correct magnetic bearing, or direction of the ship's head will be intermediate. When doubts exist in a merchant ship about the correctness of the course, the above plan of carrying a compass forward and comparing it with the one abaft, affords an excellent check against any local attraction that may arise from receiving a new *cargo*, or from making changes in the *stowage* in a vessel. * * * If the local attraction of a ship has been correctly ascertained by swinging her round, and the amount of local magnetism noted upon each of the two-and-thirty

points of the compass, then these corrections may be safely applied to the courses, so long as the ship continues to be navigated in the same amount of magnetic dip; but if the ship's local attraction has not been correctly found, we may deduce the following practical results from the principles we have been propounding:—

1st. Almost all ships will be found nearer to the magnetic equator than the dead reckoning will place them: thus in England, or in north magnetic latitude, ships get to the southward of their reckoning; but at the Cape of Good Hope, or coast of Brazil, they generally get to the northward of their reckoning.

2d. With regard to the change which takes place in the polarity of the iron in a vessel as she changes her position, and which involves important considerations to the navigator, we may deduce the following general rules:—

3d. In north magnetic latitude, and when a ship is on a wind, and steering a northerly course, she is liable to be to leeward of her reckoning; but when steering to the southward, she is liable to be to windward of her computed position.

4th. In south magnetic latitude, and when a ship is on a wind, and consequently inclined, she is liable to be to leeward of her reckoning when standing to the southward; but liable to be to windward when standing to the northward.

So that in any magnetic latitude, whether north or south, a man-of-war, when on the wind and steering towards a magnetic pole, is liable to be to leeward of the reckoning; but when standing towards the magnetic equator, and inclined by the force of the wind on her sails, will get to windward of her place by dead reckoning, when all other things are equal.

We must go a little further into our subject, and remind our readers that the general mass of the metals being in every ship *below* and *before* the steering-compass, the magnetic needle is acted on most powerfully by the *nearest* magnetic pole of the iron before it, and that the greatest effect is produced when the compass-needle is nearly parallel to the ship's beam, or at right angles to the keel. If the ship be *perfectly upright*, and both sides perfectly alike with regard to the iron entering into her fabric, then, when her head, or rather her keel, is in the direction of the magnetic meridian, the local attraction on the compass is $= 0$; but when the ship's head is either magnetically east or west, the local attraction is a maximum; the vessel being supposed *perfectly upright*. But if the ship be inclined from an upright position, the induced polarity of the iron in the vessel is transferable from side to side; and the local effect upon the compasses under these conditions is greatest, when the ship's head is on the magnetic meridian, and least, when either east or west. Now when the ship's course is either N. E., S. W., N. W., or S. E., it is evident the local magnetism of the general mass of the vessel, and her contents, as ascertained when perfectly upright, may either go to cancel, or combine with the magnetism arising from a change of the ship's inclination from starboard to port; *although the direction of the ship's keel may not change!*

*Ex. gra.* Let a ship be steering a N. E. compass course from the Longships to Milford, then it is possible that the north part of her compass may be drawn forward half a point by the local magnetism of her contents, when the ship is quite upright; consequently, although the compass might indicate a N. E. course, the ship would actually be steering a N. E. $\frac{1}{2}$ E. course. Let it now be granted that the wind may change to northwest, and that by the ship's inclination the north point of the compass-card may be drawn half a point towards the lee side of the ship, if continuing to be guided by her course by the compass, would now be steering at N. E. by E. instead of N. E. If the wind be southeast, and the ship incline to port, and the north point of her compass be drawn half a point to leeward, this quantity arising from the change in the magnetic polarity of the guns, knees, or bolts in the vessel, would cancel the other kind of local attraction, and under our conditions, the compass course would be correct on the starboard tack, but one point in error on the port tack; and in this way the quantity that the north point of the compass-card might be drawn forward by the general magnetism, might be either cancelled, or doubled, by the quantity that the north point might be drawn or driven to leeward by the ship's inclination. A commander of a vessel unacquainted with these magnetic anomalies, might, in making a passage, pronounce his compass free from error, and on another occasion might find his vessel one mile to leeward of the reckoning, for every

five of her distance run: what would he do? Why, place his errors to the account of a strange and unaccountable current!

H. M. S. "Thetis" sailed from Rio de Janeiro on the 4th of December, 1830, having on board 800,000 dollars for England. On the evening of the 5th of December she ran upon Cape Frio, and was wrecked. The weather after the "Thetis" left Rio, was rather tempestuous; it blew strong from the southeast; a course was shaped N. E. by E., by compass, and the ship ran against the cliffs of Cape Frio, her studding-sail boom-irons striking fire from the rocky cliffs, at a time when her dead reckoning placed the vessel thirty miles from the land.

Whenever inquiries are made about the loss of ships that have run ashore, we invariably find the *currents of the ocean* are assigned as the cause. It is even probable that a current may have set the "Thetis" to the westward, but we are certain that the local magnetism of the ship would have the effect upon her steering-compasses of indicating a course more easterly and less northerly than the ship was steering. Vessels steering a northeasterly course in the English Channel, invariably get to the southeastward of their reckoning. Now the "Thetis" being in *south magnetic latitude*, would diverge to the *northwestward* of her reckoning, and it is not necessary to have recourse to an imaginary current to account for her loss.

We are sometimes told that a binnacle-compass will not be influenced by a ship's local attraction, if her keel coincide with the direction of the magnetic meridian. But this opinion is incorrect, and founded on the supposition that the local magnetism of a ship may be referred to a *central point* near the middle of the vessel, and that it remains constant, an opinion at variance with the doctrine we have detailed, and the demonstrations we have given. The errors that creep into a ship's reckoning no doubt frequently arise from currents. Navigators may likewise get out in their reckoning by making allowances for currents that do not exist; but the great source of errors in navigation consists in bad steerage, and ignorance or inattention to the magnetic attractions and repulsions of the iron in a vessel, which derange the compass courses.*

The general use of chronometers, the correctness of our logarithmic tables for practical astronomical purposes, the accuracy of our astronomical and mathematical instruments used for naval purposes, have left us little to desire for all the purposes of practical navigation, so long as *the state of the weather* will allow us to make astronomical observations. But these have made navigation so easy and accurate in *clear weather*, that the necessary care and attention under ordinary circumstances to the *helm*, *log*, *lead*, and *lookout*, have been sadly neglected by the majority of seamen. The result has been, that worse dead reckonings are now kept than ever were kept before. The general adoption of iron in the construction and equipment of ships, deranges the compass courses, and a record is made on the log-board, of courses that the ship never steered; that is, the log-board only shows a compass course, instead of the magnetic course, uninfluenced by the local magnetism of the ship or her cargo.

When an observation for the latitude is obtained at noon, this latitude enables the navigator to correct his longitude by dead reckoning, and also to work out his sights for the chronometer; but when a ship has been a day or two without obtaining an observation to determine her latitude, there may be a considerable error in the latitude by account. Now if sights be obtained for determining the longitude by chronometer, and the mean time for these sights be obtained by applying to the calculation a latitude which is not the latitude of the place where the observations were made, it is evident that the longitude obtained by such a calculation must be wrong.

The makers as well as the managers of mariners' compasses should thoroughly understand the elementary principles of magnetism. The compass, like chronometers and other useful machines, should be submitted to some test of its efficiency after it is made, and before it is offered for sale, or brought into use at sea. The compass, although less costly than even a common watch, is infinitely more useful than the best chronometer. A compass is not sub-

* Quere. Could Lieut. Maury have been unmindful of these considerations in the publication of his "*Wind and Current Charts?*"

jected to any trial or test of its accuracy of manufacture, its magnetic intensity, or the amount of its friction on the pivot upon which the card traverses, and the amount of its directive power, compared with the weight of the needle and its card. Generally, we may remark, that neither the vendor nor purchaser of a compass knows much about these matters; the former being satisfied if he realize a good profit, and the latter being pleased if he purchase a handsome article.

The essential qualities of an efficient compass, are, great directive power combined with little weight or friction on the pivot, the compass-bowl being freely slung in jimbals attached to the box, so as to preserve a horizontal position under all cases of the ship's rolling or pitching. The steel of the needle should be of pure metal, of uniform hardness throughout, and magnetized to saturation, and the magnetic intensity of a compass-needle should be preserved with all possible care. We have said that a compass-card should be submitted to some test. Now a very fair and efficient test of the magnetic energy of a compass-needle is to try if two similar cards will by their mutual magnetism support each other's weight; that is to say, if the north point of the needle of one card be applied to the south point of a similar one, and their mutual attraction be such as to support the weight of the card, the magnetic intensity of such needle may be regarded as sufficiently strong if they mutually support each other's weight, along with the cards they respectively carry. Now the magnetic intensity or power of every compass-needle, should remain permanently a constant quantity, and this can only be accomplished by each ship being supplied with a pair of artificial magnets of sufficient power to renovate the magnetism of the compass-needles whenever the test might indicate that they required re-touching. The magnetism of a single needle is probably best preserved by allowing it to traverse freely on its pivot, or else to be stowed in a direction parallel to that of the magnetic dip, for if it be placed, say, with its south pole (or north point) towards the south pole of the world, or *vice versa*, its magnetic intensity will decrease; or, if a compass be placed near to a large mass of iron, in such a manner that the magnetic polarity of the iron may act so as to control the magnetism of the compass, to a certain extent, by acting in a contrary way to that of terrestrial magnetism, then will the magnetism of the compass-needle be deteriorated. If, for example, the south point of a compass-needle were placed near to the upper end of a vertical iron pillar, the needle would be deprived of a portion of its magnetism; but if the north point of the card be placed near, or in contact with the upper end of the pillar, (in north dip,) the magnetic energy of the compass-needle would be augmented.

It is under such circumstances as are described by Falconer in his "Shipwreck," that we are taught to appreciate the worth of a good helmsman, and the value of an efficient compass. One card is exchanged for another, and weak needles are loaded with heavy weights in order to lessen the oscillations, but neither brass bars, nor brass rings, wax, paper, nor talc, can cure the evil; for as we increase the weight and friction of the card, we only make it the more sluggish, and unfit for the helmsman's use, who, instead of being guided by the compass in the binnacle, must ever and anon keep looking *ahead* at the clouds, the waves, or the stars, for he finds that a sluggish compass does not indicate a change in the direction of the ship's course until some time after that change has taken place.

The generality of seafaring men are not so well informed about magnetism as they should be: how can they? since philosophers differ in opinion about their respective theories! We have touched but lightly on these theories, as our object has been rather to teach the navigator a few of the fundamental principles of terrestrial and inductive magnetism, upon which the practical utility of the mariner's compass depends.

It will be borne in mind that the brief outline of modelling and construction, which we have here given, refers entirely to *sailing* vessels—there being necessarily (from the dissimilarity of circumstances) a material difference in the construction of *steamers*. These variations may be enumerated in a few words. As we have seen from an examination of the foregoing rules, that length is essential to sharpness, and sharpness to

speed; and since speed is more important than capacity for cargo in a steamer, the sacrifice of the latter is made in order to overcome the increase of resistance which arises from the increase of the propelling power.* Hence the length of steam vessels, in lieu of being limited to four and five times the breadth of beam, is extended to *six* and *seven* times that quantity. Another material feature is, that the centre of buoyancy (at the line of floatation) is *abaft*, instead of forward of the centre of the vessel: the reason for which is manifest when we consider that the action of the wheels has a constant tendency to raise the bow out of water, and to depress the stern; the consequence of which is to cause the vessel (when in motion) to sail upon an *uneven* keel, or, in nautical parlance, to "*squat.*" Hence it becomes necessary to bring the predominant portion of *buoyancy* abaft, in order to counteract this effect—an effect which is highly objectionable in a sea-way, as involving, to a very considerable extent, the safety of the ship. Again, too, we perceive that the *floor*, instead of being formed with a dead rise, (as in the case of a sailing vessel,) is almost entirely *flat.* This may be very readily accounted for from the fact, that a horizontal floor is found to be more advantageous for the attainment of speed than any other shape, by giving the vessel a greater amount of buoyancy; while, at the same time, it obviates in some measure the sacrifices of strength and capacity, which result from the *comparative* increase of length. And since the movements of steamships are less controlled by the elements than *sailing* vessels, the same reasoning which compelled us to construct the bottom in one case at an angle, manifestly cannot apply to another which does not involve identical conditions.

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## TRIM.

Glascock (to whose work we have already made many references) says: "Surely if stowage be considered in the light of a science, and if the naval architect can construct and complete a vessel purporting to possess certain properties, the builder should be competent to lay down positive data for the guidance of her stowage." This is true to a certain extent—so far as it affects the *distribution* of *weight*, and the *stability* and *sailing* qualities of the vessel; but it is manifestly erroneous to suppose that the builder can "lay down" rules for the *arrangement* and *preservation* of particular articles of cargo, which apart from not falling within the province of his branch, are not even known to him.† A view so limited as that which might be gleaned from the constructor, would be of no practical utility in a *commercial* application, as involving only the first principles of the science of stowage, or, in other words, that branch of it which constitutes *trim.*

Let us consider, then, the influence which trim exerts upon the *safety* and *speed*

* Vide Booth's Tract on the "*Theory and Practice of Propelling through Water.*"

† The author of the "Manual" might, with the same reason, have maintained that the Chinese who "can construct and complete" a set of *chess-men* "should be competent to lay down positive" rules for the game!

of the ship; for it is evident that the distribution of weight is indissolubly connected with those points in the model upon which safety and speed are dependent; while stowage, or a *profitable* arrangement of cargo, (giving it the simplest acceptation,) refers exclusively to *capacity*. Indeed, the want of proper signification to these terms hitherto, has tended more to confuse professional writers and readers than the total absence of every written article upon the subject in question. It will be seen, moreover, that when a line of demarkation is thus drawn, a twofold view is presented, yet holding a relationship to each other which is inseparable; for it is plain, that however independent of mere *shape* and *form* the arrangement of cargo may appear, nevertheless, if it be stowed without regard to stability, and the equal distribution of *weight*, we necessarily jeopardize the safety of the vessel, and as a matter of course the cargo itself. Under these circumstances, an acquaintance with the general principles of construction is absolutely essential; for without a knowledge of the build, even the architect himself would be incompetent to direct us in regulating the trim, and without trim, "successful stowage" would be impossible.

But let us see how far the brief views which we have given of construction enable us to investigate the principles of trim, and also to what extent the builder is "competent to lay down positive data," from his knowledge of the lines, and form, and displacement of the vessel.

1. As a general rule, every ship, in loading or in ballast, should trim, *as she sits upon the water when launched;* and since (as we have seen) the centre of *buoyancy* is forward of the centre of displacement, the *after* part of the ship will necessarily be deeper immersed in the water than any other; hence she will trim by the stern. But apart from this being a consequence resulting from the peculiar *form* of the vessel, there is also an important reason why such should be the case to a certain extent—viz. that the rudder has more power upon the water, by exposing a greater amount of surface to its action, and the vessel is found to require less weather helm than otherwise. This latter result arises from the comparative lightness and buoyancy of the vessel forward, and the unequal lateral pressure upon the extremities, which (as philosophy teaches us) is directly proportioned to the depth of immersion. Yet however essential it may be for the generality of vessels to trim by the stern, there are limits beyond which it would be obviously impossible to go, without proving detrimental to speed and safety. In some cases, the amount of this difference in draught is greater than in others, which depends upon the form of the vessel, and the distance of the greatest breadth before the centre of displacement. Under these circumstances, it is manifest that no rule or limit, by which this difference can be estimated, can be laid down, since no two vessels involve the same precise conditions of length, and breadth, and depth of hold. At all events, it would be well to bear in mind, that the difference between the draught of water forward and aft, in loading a vessel, should never exceed that which it was at the time of her launching.

2. As with all rules, however, this is not without the exception; and in those cases where the floors are lengthened beyond the usual limits, (as referred to on page 5,*) the extremities are sharpened in such a proportion as to make the centre of buoyancy correspond with the centre of displacement; consequently the *trim* of the ves-

* Within the last ten years, this feature in construction has been practised to a very considerable extent by the builders of this city, (New York.)

sel, either at the launching or subsequently, will (in accordance with the principles we have stated) be found to be upon an even keel.

3. Another exception affecting the relative draught of the vessel, forward and aft, is met with in deep loading; and in illustration of which it is only necessary to consider, that as the hull settles down in the water, the lines become (comparatively) fuller aft than forward, on account of the flare and flatness of the counters and run, while at the same time the buoyant tendency is carried in the direction of the increase of surface. From this, it is easy to deduce, that a vessel trimming in ordinary cases by the stern, will, on being deeply laden, float upon an *even* keel; and another, the naturally "sit" of which is horizontal, will, under similar circumstances, trim by the *head*.

4. "The centre of gravity of the mass (of the cargo) must neither be too high nor too low in the hold—the former will cause the ship to be top-heavy and laborsome, and the latter will make her crank; and in the adjustment of the larger and heavier masses, it must be recollected that the effect of every weight belonging to a ship in increasing the angles of the pitching motion, is in exact proportion to its amount of inertia;"* for, as Glascock observes, "few ships will admit of weight being placed in either extremity." The fallacy of placing weight in a vessel's extremities, is illustrated in the case of the U. S. sloop-of-war H——, during the war of 1812, on board of which, in order to make room in the hold for the stowage of a larger amount of provisions than usual, the magazine bulkheads were removed further *aft*, and the ballast stowed in tiers against it up to the lower deck, in lieu of being winged out upon the floor, as in the usual way. The result of this *experiment* was, that on encountering a very moderate gale soon after leaving New York, (from whence she fitted out,) *every stern and quarter boat* in the ship was swept away, in consequence of the inability of the stern to rise beyond the reach of the sea. Subsequently the vessel was chased by an English 74, and notwithstanding the previous sailing qualities of the H——, it was found impossible to make her go over eight knots, even under the most favorable circumstances of wind and weather; and it became necessary, in order to avoid capture by the enemy, to throw overboard not only every moveable article upon deck, but guns, stores, &c., &c., until the original trim was in a measure restored, when she made good her escape.

These principles apply equally to vessels of war, with some slight exceptions, which unavoidably result from their peculiar design and construction; we shall, however, take occasion to refer, under their proper heads, to such points as may be of importance.

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## BALLAST.

As stability and speed are the desirable features of a man-of-war, and strength and capacity especially those for a merchantman, there arises a marked distinction in the guiding rules for ballasting; for while the former requires ballast, the nature

* *United Service Journal*, Sept. 1836.

of the cargo in the latter, is often such as to obviate its necessity. In order therefore to avoid confusion, it is important that the stowage of each class should be stated separately.

In the naval service the practice is as follows:* First prepare the hold for the reception of the ballast, by having it thoroughly cleaned and whitewashed, and the limbers cleared. Having beat the rust off, and weighed each pig, commence stowing at each side of the kelson, on the skin, and extend it fore and aft between the fore and mizen masts,† observing to have the same quantity on each side, and the greatest spread in winging out, athwart the greatest breadth of beam.‡ As it is necessary to have a given quantity nearest to the kelson, and about the greatest capacity, one would be obliged in a sharp-bottom vessel to form several tiers, one above the other, while with a flat floor the same quantity would be contained in a single spread. But whatever circumstances control the arrangement of the ballast, it must be remembered that an uneven stowage in the lower extremities of the vessel would necessarily produce an irregularity in the surface of the tanks, and indeed affect the general stowage of the ship throughout. After having thus placed the ballast, make a draught of it, illustrating its position and weight, and prepare for getting in the tanks.§

In the calculation of a required amount of ballast for a man-of-war, the rule laid down by Fordyce is perhaps the simplest and best—viz.: Divide the number of tons by 8, and the quotient resulting therefrom by 5—then subtract the second quotient from the first, and the remainder will be the amount of ballast in tons.

EXAMPLE.

8 ) 750 . . . = tonnage.
5 ) 93 (nearly) = 1st quotient . 93
17 . . . = 2d " . 17
Difference 76 tons.

It is manifest, however, that the weight of tanks, cables, and shot should be included in this allowance.

NOTE.—In some of the newly-built vessels, as the "Plymouth," &c., pig-ballast has been omitted, as the weight of the tanks, shot, chain-cables, &c., has been found sufficient to preserve the stability.

To take the merchant service. We will suppose a ship requires stowing in simple ballast for a voyage to China, or the coast of Sumatra, as it is only with light cargoes, or none at all, that ballast is employed. This usually consists of refuse pa-

* The major part of this is abridged and revised from *Totten*, as emphatically the "*Text*" of the naval service.

† "Every weight placed in either extremity, or before or abaft the centre of gravity, tends more or less to augment the force of the pitching motion."—*Glascock*.

‡ Captain Skiddy recommends, that in lieu of *spreading* the ballast out to the wings, as suggested by Totten, it be *tiered* up on each side of the kelson, in such a manner as to form (in a sectional view) a triangular surface, having the apex in the centre of the vessel, so that in rolling, the weight at the extremities of the beam, or the *leverage* (so to speak) of the ballast, will be less remote from the fulcrum, and thereby check the otherwise *sudden* return of the vessel after having careened.

§ Vide page 53, for the stowage of the hold and spirit-room.

ving-stones, as the cheapest and most available, although common beach-gravel, or *shingle*, as it is technically called by stevedores, is considered the best, on account of making better stowage, and doing less injury to the bottom. This, however, is not always easily obtained, and consequently is the most costly of any, if we except iron, which is never used.

*Sand*, as ballast, should never be employed, if it be possible to avoid it, on account of the liability to work through the ceiling, and choke the pumps. When other ballast cannot be obtained, however, and there is no alternative, a careful, considerate seaman would take the precaution to cover the ceiling of his vessel with mats or old sails. Indeed, this is the only sure means of precluding the access of the sand to the pumps;* and the only means by which the pumps can be cleared, and *kept cleared*, is to have the well made sufficiently large to admit of sending a man down for that purpose. This plan was adopted on board of the packet ship "Constellation," and should be followed by every builder.

An important reason, also, why sand-ballast should not be employed is, that it is often injurious to the cargo, by becoming mingled with it, a case of which is recorded in the journals of the Port-Warden's office of this city: On board the bark ———, loaded with cotton, and ballasted with sand, the major part of the cargo was damaged to a very considerable extent, in consequence of the particles of sand being washed into the sacking of the cotton-bales, by water blowing through the ceiling on the rolls of the vessel. It is unnecessary to say which of the parties interested became responsible. Another consideration of no little magnitude in the use of sand-ballast is its tendency to *stain* the exterior surface of cases and casks; and such is the importance attached to this species of injury, by merchants and consignees, that it is often made the plea for a remission of duties; and in one or two instances the entire cargo was sold at a sacrifice. The following is a case in point, which I have noted from the journals referred to: A schooner laden with wine from one of the Mediterranean ports, was stranded near New York, and in consequence of which, the casks were more or less stained by the oxidation of the hoops, from being rolled up on the wet sand, although no part of their contents was damaged in the least. The result of the matter, however, was that the duties were remitted, and the cargo sold for the benefit of the underwriters, and for no other reason than the unmarketable appearance of the casks.

Note.—At Antwerp it is impossible to obtain other than sand-ballast, and this, from being taken from the bed of the river, is so saturated with water that masters of vessels are often deceived with regard to the requisite quantity; as after getting to sea, the pumps remove the water, which settles in the bottom, and with it, of course, the major part of the *weight*. It is therefore recommended to bring the vessel down to a good depth of draught before sailing.

*Copper-dross*, although expensive, is often used for ballast on account of its great

* "We sometimes hear of vessels having put into ports with pumps choked by sand-ballast. If from parsimony or other unworthy motive, sand-ballast has been preferred to stone, or other proper ballast, a shipowner ought to be held liable to make good any damage suffered in consequence. If a master be so situated that he can obtain no other than sand-ballast, it then becomes his *duty* to use every precaution possible, by caulking the ceiling, clearing the limbers, and by protecting with matting, &c., that the pumps may not be choked with it: but, with every precaution, he is not warranted in taking sand, if stone, metal, or other such ballast can be obtained."—*Lorimer's Letters*, page 40

specific gravity, and the advantage it affords in making *small* stowage. It is liable, however, to the objection which has been urged against sand—viz. of staining the cargo. This, nevertheless, is obviated in some measure by covering it with plank; but under any circumstances, there is no ballast so well calculated, or so free from these objectionable features, as shingle or lead.

Vessels bringing cargoes from French ports, as Bordeaux, Nantes, &c., not unfrequently carry a sufficient quantity of *meule de moulin*, (or the common *buhr-stone* of commerce,) to answer the purpose of ballast, which at the same time serves for dunnage.

As a general rule, for a ship "in ballast," 30 tons to every 100 tons of *custom-house* measurement will be found sufficient; but it must be borne in mind that a small vessel requires a greater quantity of ballast (in proportion) than a large one, on account of the loftiness of her spars, and the amount of top-hamper, which tend to press her over under sail.

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## DUNNAGE.*

Upon this subject pages might be written,—First, as to what cargoes require dunnage; second, of what it should consist; and, third, of what height it should be, on the bottom of the vessel when used. The answers to these questions, though involving cases, which would in detail furnish materials for a library, are briefly thus: All *perishable* cargoes require dunnage of *some* species; but what *is*, and what is *not* a perishable cargo, is a question so foreign to the matter in hand, that it is unnecessary to make the definition here. It is sufficient to know that even where every precaution has been taken to dunnage a cargo, ulterior causes have arisen during the voyage of importation, to render it utterly unsaleable, except at a wanton sacrifice. To take a case in point, which is cited from the journal of the Port-Wardens thus:† A vessel cleared from New Orleans for New York, with a cargo of *corn* and *pork*—the former stowed in bulk in the lower hold, and the latter between decks, in boxes filled with salt. On her arrival at New York, it was discovered that the pork was almost entirely spoiled, and yet the *stowage* of the ship was such as to justify the inspecting wardens, in giving the captain a clear certificate. This, however, did not compensate the merchant, who sued for the recovery of damages done to his pork, which had been shipped according to the bill of lading, "in good order and condition." On investigating the matter, it was found that the *heat* from the corn (which had been imperfectly dried before shipment) had absorbed the moisture of the salt, and resulted in the damage in question. But whose fault was this? Not the captain's, or the stower's surely. Both articles of cargo were prop-

* For many of the cases cited in this article, and for much valuable information, embodied in other parts of the subject of stowage, I owe acknowledgments of obligation to Capt. W. W. Story and his assistant wardens.

† Names and dates are purposely omitted, as many of the cases here cited are either of recent occurrence, or have been adjusted by compromise.

erly dunnaged and secured; and beyond this the captain could not, nay, ought not to go. It is sufficient for him, that a case or bale or box is brought down for shipment, and as simple *freight:* if he secures it from damage against the ordinary perils of his voyage, he does his duty, and is so far irresponsible to the consignees of his cargo; but it is manifestly unjust to hold him accountable for damages which originate in the cargo itself, and which arise from no fault of his. A similar case is cited of a shipment of *flour*, which became sour and musty, apparently from the same cause, &c.

In reference to the question of what the dunnage should consist, it is at best but a matter of opinion in its very nature, and as such cannot be responded to, except in such general terms, as to be wholly inapplicable to particular cases.* Ordinarily, firewood, refuse boards, and plank, old sails, mats, bamboo, &c., &c., are used for this purpose: but it would be well to bear in mind, as an acknowledged principle, that the captain has *no right to use any article of cargo for dunnage*, without being strictly responsible for damage done to it. In the shipment of *coffee* and *hides*, however, there is a partial exception to this which arises from the custom of South American countries. There the hides are used in all cases as dunnage for the coffee: still the principle we have laid down holds good—viz. if either suffers damage from this cause, the captain is, and should be accountable. Again, to take a case in point. A vessel arrived at New York from Rio de Janeiro with a cargo of coffee and hides stowed thus, and under the following circumstances: The floor-heads and bottom of the vessel were covered with rosewood dunnage to the height of eighteen inches. This was in turn covered with hides to the depth of six inches or more, and mats laid fore and aft upon them; after which the lining of the vessel was ceiled over with one or two thicknesses of hides, and the coffee-bags then stowed in bulk. Notwithstanding these precautions, on the arrival of the vessel, the whole cargo was found to be damaged, more or less, from leaks in the deck and the heat of the coffee. So far as the latter was concerned, this was pronounced by the portwardens to be good stowage, as being in accordance with the custom of the country; nevertheless the damage to the coffee arose in a great measure from the putrid condition of the hides, which spoiling, from the effects of dampness and heat, ruined in turn the coffee.†

Lastly, with regard to the *height* of the dunnage, it is admitted on all sides that *six* inches is sufficient (using the language of custom) "to carry the world over." Nevertheless, there is no law,‡ beyond the law of common usage, which compels the

* One thing, however, must be remembered—viz. that *green*, or *wet* wood should not be used for dunnage, as it would not only damage the goods, but *rot* the ship also.

† Had dunnage been placed between the hides and the side lining of the ship, they would, in all probability, have escaped, as in nine cases out of ten (if we except sweat) the damage done to cargoes arises from water blowing through the ceiling.

‡ "I am not aware that there is any established rule as to dunnage, but from information derived from experienced persons, I understand that there should not be less than six inches in the flat bottom, and nine in the bilges. My informant, speaking of the arrangement of a West India cargo, says: 'It is the duty of masters to provide plenty of wood for dunnage and chocks, and not to dunnage less than six inches in the flat bottom, and nine in the bilges. Hogsheads to have three beds under each. Casks of rum, molasses, &c., to be well bedded and quoined off, with bungs up; to be stowed on their bilges, and well chocked; and on no account to exceed four heights of riders. To be careful not to stow rum, molasses, or other liquids, on sugar, coffee, or any other goods liable to be damaged by their leakage. If coffee, pimento, or other goods in bags, should form part of the

use of dunnage; and if the cargo suffer no damage without it, the stowage of the ship, if not *good*, will at least be sufficient to justify the inspecting wardens in the execution of a clear certificate. This height of six inches is therefore not arbitrary, as a lesser is often admitted. For instance: a vessel arrived from Rio with a cargo of coffee and hides. This was dunnaged in the ordinary way to the height of *four and a half inches* alongside the kelson, and gradually tapered off to about *two and a half* on the floor-heads. The result was, the lower layers of hide were found to be damaged considerably, and the wardens decided that although the dunnage amidships was such as to warrant the opinion of "good stowage," that in the wings (for it was there only that the cargo was damaged) was insufficient for its protection. This opinion, however, was not induced by what they regarded a violation of the law of usage, but what was evident neglect on the part of the stower, who should have known that the pumps could not remove the water from the bilge when the vessel careened. From this it is easy to deduce one or two important points in reference to our subject: first, that dunnage is less necessary (in ordinary cases) alongside the kelson than in the wings; and, second, that a *flat*-floored ship requires more dunnage than one in which the dead-rise of the bottom is greater. Yet however essential *under* dunnage may be for the preservation of the cargo, there are other parts of the hold from which the goods must be protected, as the pump-well, masts, stanchions, &c., &c. Nor is dunnage of itself the only preventive against damage; other precautions must be taken for its security, and unless there be evidence of care, not only in the stowage of the cargo, but in the fastening of hatches, &c., the carrier is, and should be responsible for resulting losses.* The following case is cited in illustration of this point: A vessel arrived at the port of New York from the West Indies with a cargo of sugar. On opening the upper hatches, the lower deck was found to be flooded with *syrup*, to the depth of several inches, and

cargo, they may be stowed in a vacancy by themselves, or on the other cargo, provided the cutlines of the casks be well filled with wood, &c., to prevent the bags from being chafed by the working of the casks at sea. If a vessel have the lower deck laid and caulked, it will be necessary to dunnage it also.' What is here said of a West India cargo will apply to all others. In an entire cargo of raw material, such as cotton, it may not perhaps be necessary to have the vessel's sides so much protected, but there ought to be no diminution of dunnage in the bottom. In outward cargoes of dry goods, the precaution should rather be increased."—*Lorimer.*

* "The greatest care with regard to dunnage is sometimes rendered of no avail, owing to neglect of the *pumps*: not so much neglect of them at sea, for a regard for self-preservation generally forces the most careless to establish rules for periodical pumping during the voyage, but neglect while lying in harbor. It frequently happens that a vessel is taking in cargo for a length of time previous to sailing; during that time the captain may be living on shore, and may have left the charge to those who have not taken care to sound the pumps occasionally. When the vessel has been at sea a few hours, the master is surprised to find a great accumulation of water in the hold, and the consequence may be, that he or his owner has to pay smartly for weeks of neglect. A case of this kind was tried some time since at Lancaster, (England,) and the verdict of a jury forced the shipowner to pay a serious sum for sugars thus damaged. It came out in evidence, that while in harbor the vessel had not been pumped out for *six weeks*. At sea, when a vessel has been lying over for some time on one tack, a careful master will occasionally bear up, sound the pumps, and, if necessary, clear the hold. This is the more necessary, if the vessel has not bilge pumps. Another and frequent cause of great damage is the neglect of caulking the vessel's top sides, &c., during the time she is lying in port in a tropical or warm climate, and immediately before sailing thence on her voyage home. The great heat causes the exposed seams to open in a very short time, so that, if they be not caulked immediately before the homeward voyage commences, she may, in a few hours after sailing, be suddenly found to have four or five feet water in the hold."—*Lorimer.*

many of the hogsheads quite empty. The supposition was, that the sugar had been made from *frosted* cane, inasmuch as the upper deck was found to be perfectly tight; but on removing the lower hatches, the cargo below was discovered to be perfectly safe and good. This of course gave rise to many conjectures as to the cause; and on a closer examination it was found that one of the *air*-ports between decks had been improperly screwed in before the departure of the vessel. It is needless to say, upon whom the responsibility fell.

To enter into a statement of every case that has occasioned difficulty between the carrier and the consignee, even within a limited period, would, as I have before said, occupy volumes. It will be sufficient therefore to cite only such cases as bear directly upon the matter in hand, whenever and wherever they may be necessary to elucidate a principle or to establish a rule of observance.

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## SWEAT, OR FERMENTATION.

To attempt a complete analysis of the nature and origin of sweat in the hold of a vessel, would require more space than the limits of this work will allow. It will therefore suffice to allude simply to the cause of its existence in certain articles of cargo under certain circumstances, and to state briefly the means by which it may be prevented.

With such articles as uncured grain, unripe fruit, newly-made sugar, green coffee, &c., the fermentation, or generation of sweat, is found to be very considerable. This arises from the changes of the atmosphere, and the energetic affinities of oxygen, hydrogen, and carbon, which produce a liability in all vegetable substances to spontaneous decomposition.* So long indeed as they remain in connection with the living plant, by which they were produced, the tendency of their elements to form new combinations is controlled; but as soon as the vital principle is extinct, as it were, they become subject to the unrestrained influence of chemical affinity, and unless the moisture be expelled by artificial means, these spontaneous changes (to which the term sweat or fermentation is applied) at once ensue. This change sometimes terminates in the formation of sugar; at another time, in that of alcohol; at a third, in that of acetic acid; and at a fourth, in the total dissolution of the substance. This has led to the division of the fermentative processes into four distinct kinds; namely, the *saccharine*, the *vinous*, the *acetous*, and the *putrefactive* fermentation. It is only necessary, however, for us to consider the latter. The conditions which are required for enabling it to take place are *moisture*, *air*, and *a certain temperature*. The presence of a certain degree of moisture is absolutely essential; and hence vegetable substances, which are disposed to putrefy under favorable circumstances, may be preserved for an indefinite period, if carefully dried and protected from humidity. Water acts apparently by softening the texture, and thus counteracting the agency of cohesion; and a part of the effect may also be owing to its affinity for

* The major part of this analysis is extracted from Redfield's Family Magazine, Vol. III., page 449, and modified to suit the subject under consideration.

some of the products of the putrefaction. It is not likely that this liquid is actually decomposed, since water appears to be a uniform product. The air cannot be as absolutely necessary, since the putrefactive fermentation or sweat is found to be produced by the concurrence of the two other conditions only. Its presence is attributable to the oxygen in the hold combining with the carbon and hydrogen of the decaying substance. The temperature most favorable to the process of putrefaction and the generation of sweat is between 60° and 100° Fahr. A strong heat is unfavorable, by expelling moisture; and a cold of 32° Fahr. (at which water congeals) arrests its progress altogether. The mode in which caloric acts is the same as in all similar cases, namely, by tending to separate elements from one another which are already combined.

This fermentation, originating among the cargo of itself, and apparently beyond the control of any subsequent care on the part of the carrier, should release him from the responsibility of losses which might result from its presence. The following instance is cited to show the unavoidable and natural existence of sweat: A vessel cleared from New Orleans with a cargo of cotton and corn—the latter stowed in the hold in bulk, and the former between-decks. On reaching a northern latitude, at an inclement season of the year, the sudden change of temperature produced an active fermentation of the corn, and the result was, that the greater portion of the cotton was damaged, in consequence of the bales absorbing the globules of moisture, which had congregated on the under side of the spar-deck, and in immediate contact with which they were stowed. Attention must be paid therefore to the stowage of goods near the deck, particularly on going from a warm to a cold climate. The air in a ship's hold continues warmer than the exterior air, and the vapor from the bilge-water rises to the deck, where, from the coldness of which, it is condensed, and falls down in the form of rain upon the goods. This is not the case, however, when going from a cold to a warm climate, as the warmth of the deck then absorbs the vapor.

From an examination of the journals in the Port-Warden's office from 1816 up to the present time, it appears that within the last ten or fifteen years more cargoes have been damaged from the action of sweat, than during any previous period. By way of accounting for this, Captain Story has suggested to me that in former times, the cabins of vessels were built below-decks, and by means of which, stoves, and the existence of a free current of air, dissipated the moisture arising from the hold, while now-a-days the air has little or no access to the cargo in consequence of the cabins being constructed above.

As we have seen from the analysis already presented, that the sweating of a cargo arises under certain circumstances of moisture and temperature, or in other words from an unnatural and impure condition of atmosphere, it follows that *ventilation*, or the creation of rapid and changing currents of air, (since air is unessential to the existence of sweat,) is the only means by which this fermentative tendency of the cargo may be permanently checked—I say *only*, for if we consider the circumstances of a ship at sea, and the limited sphere in which we are necessitated to act, it is manifestly impossible to expel moisture by other means.

Finally, then, with regard to a system of *ventilation*, that adopted in the packet ship "Constellation" (already so often alluded to) appears to involve every possible contingency; and it will suffice for our present purpose to refer to that in general terms.

Two sheet-iron pipes, varying from twelve to eighteen inches in diameter, and having large mouth-pieces, susceptible of being turned in any direction, are constructed at each side of the bowsprit. These extend from the forecastle-deck down to the lower hold, gradually decreasing in size, and fitted with doors, or valves, opening on every deck. In like manner, pipes are placed up and down the stern frame on each side, for the discharge of foul air, which is thus expelled from the hold. Each hatch is also supplied with a skylight, opening on top, and both forward and aft; and the air-ports above and below are constructed with pipes extending down inside of the lining to the turn of the bilge. Another feature in this system of ventilation is the construction of an efficient *air*-pump in the centre of the well, and which (in addition to being also used for *water* in case of necessity) is worked upon the same shaft as the other pumps of the ship, while the forecastle ventilators may be employed for a similar purpose of expelling foul air from below, by having their mouth-pieces turned *from* the wind, whereby a partial vacuum is created at the opening on deck.

A system so perfect in every particular as this, emphatically casts *ship-fever* "to the winds," and bids defiance to that rankling pestilence, which, alas! has so often hitherto followed in the wake of some ill-fated ship, marking an almost *unbroken* track across the ocean, with the uncoffined victims of exile and death!

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## RESPONSIBILITIES.

*The trust confided to the master of a merchant vessel is of a twofold nature, namely, of life and of property: a trust of great and serious responsibility, and it behooves a man well and truly to examine himself before he presumes to undertake it. For, should a loss of life ensue from gross ignorance or other unfitness in the master, the plea that he ventured his own life with those of his shipmates will not excuse him here, nor avail him hereafter. Sailors, generally speaking, are a thoughtless class of men, making wages a first consideration, and taking it as a matter of course, that he who hires them has all the qualifications requisite for his situation. All responsibility may be said to be removed from them. If loss of life therefore can be traced to the misconduct of the captain, to gross neglect of duty, to drunkenness, for instance, what shall we say then? It is not for us to judge what he has to answer for; should he escape himself, none could envy those reflections which must, and most assuredly will, accompany him to the latest period of his existence. Loss of property from similar causes will, to a well-regulated mind, be nearly as burdensome. It is often wondered that some legislative regulation has not been made in this country, which would subject those who apply for the command of a merchant ship to the examination of competent persons—of persons who would search them thoroughly, not only with respect to their qualifications as practical seamen, but on many other points equally necessary to constitute the character

* Vide "*Lorimer's Letters to a Young Master Mariner*," p. 19.

of an able master; and, after all, would pass them only on the production of certificates of former good conduct and sobriety. Whether such a regulation would be consistent with the principles of free and unlimited commerce, and the rights of the individual, is not for us to say. If loss of property were the only thing under consideration, it would perhaps be as well not to interfere; we might let those who trust that property to unskilful and incompetent persons suffer for their folly; but when human life is risked, it becomes a serious question for the rulers of the state whether they should not step in to prevent its being sacrificed to ignorance, or rash desire of gain. This latter observation applies to those short-sighted owners, who, too little acquainted with their own risks and responsibilities, look more to low rates of wages than to rates of abilities. Other nations have had such regulations from very remote periods, derived no doubt at that time from the older and general sea-laws. Great importance was in those days attached to the character of a master of a merchant vessel, and great care seems to have been taken before he was intrusted with the command.*

Owners of ships, be they ever so experienced and prudent, may still be deceived in the character and fitness of a master, and notwithstanding his liability to them, suffer accordingly. As to the cargo, it is true an owner of a ship is liable for the acts of his servant, but when we consider some of those liabilities, and the difficulty, when disputed, of establishing them in a court of law, and when we bear in mind also the legal qualifications of that liability under certain circumstances, we shall find that the chance of redress for an innocent shipper of goods, is often very uncertain.† Punishment for loss of life from ignorance or negligence is left to the master's own conscience.

As the duties of a master of a merchant vessel are various, so is the performance of them arduous. Whatever a master has a right to expect from a good and faithful servant, an employer from a trustworthy steward, or a principal from his agent, an owner of a ship has a right to expect from his captain; for in all these relations does the master of a merchant vessel stand to his owner. As a servant, he is bound to devote the whole of his time and attention to his master's concerns. He may not, during the period of his contract, hire out his services, or part of them, to another.‡ Common sense and even-handed justice declare it. He has no right to take advantage of his situation, and turn it clandestinely to his own private gain, even were he convinced that his owners would not be prejudiced thereby: it is dishonesty. As to his being convinced that his owners would not be prejudiced, he ought not to entertain the question at all. Whenever there is necessity for concealment on the part of the servant, there is reason to fear for his integrity. As a steward, he is bound to render a clear and distinct account of all things intrusted to his care; to keep books, wherein all receipts and payments of money are noted, with exact dates, and every particular item stated. As an agent, he has great powers when abroad, for then only is he agent in the true meaning of the word. In the absence of any specific agreement, such, for instance, as a charter

* "Le titre de maistre est titre d'honneur, d'expérience et de bonnes mœurs."—*Cleirac's Notes on the First Judgment of Oleron.* Again, by the laws of the Hanse Towns, 1597, art. 15, "No master was to be engaged without a certificate of his capability, honesty, and good conduct."

† "The *value* of the ship is the value at the time of loss. The *freight* is the freight *due*, or to become due, including that paid in advance."—*Wilson* v. *Dickinson*, 2 B. and A.

‡ *Thompson* v. *Havilock*, 1 Campbell, 527.

entered into by his owner, he can bind his owner for all lawful contracts made by him for the use and employment of the ship. Being intrusted with the command of the ship, he has, by right of that command, the power to charter the ship, to engage and fix the rate of freight, and to enter into any lawful agreement for her employment. This he can do when *abroad;* but circumstances may empower him, when at a distance from his owner, to do the same in his own country. With regard to necessaries bought, and money raised for the repairs of the ship, he can bind his owner directly or indirectly; directly by acknowledging the receipt of the same, (usually done by drawing a Bill of Exchange, which affords the holder a right of action for debt,) or indirectly by obtaining money on a bottomry bond, if the money be obtained in a foreign port, (which gives the holder the right of process against the matter pledged,) and by sale of part of the cargo. But observe, a captain cannot mix up his own affairs with those of his owner. For instance, when a bill drawn by the captain is presented to the owner of a ship, and the owner has reason to know it is in part money taken up by the master for his own use, he can refuse payment, and that plea will be a sufficient answer to an action on the bill. The master of a merchant vessel stands in a singular situation in respect to his owner—he is a partner, and yet no partner. He is a partner in responsibility for all moneys taken up, or necessaries bought on account of his owners for the use of the ship under his command; for the holder of his bill, bond, or other security, or undertaking to pay, (unless it be in the form of a bottomry or *respondentia* bond,) has the election of looking to him or his owner for the payment. This is no slight responsibility, and yet he is only a hired servant.

By the general law of all maritime nations, and so far as we have records, the owner of a ship carrying goods for hire, is looked upon as a *common carrier*. If therefore, from the insufficiency of the vessel itself, or from the negligence or other fault of his servants, any loss or damage arises to the cargo, the owner of the ship is bound to make it good. If I send a package by a common carrier hence to any other place, and that package be not delivered in the same good order as it was when taken possession of by the carrier, or if it be stolen, or otherwise lost, he is bound to indemnify me for the same; so it is with a shipowner: but as the dangers of the sea are so much greater than those of the land, there are special reservations and limits to his responsibility. For instance: though a land carrier is liable to make good a loss occasioned by robbery at any period of the journey, whatever be the force used to effect the robbery, it is not so with the owner of a ship, which may during the voyage be attacked by pirates; and from this loss, being a "danger of the seas," he is exempt by the bill of lading. But if (and I pray you mark the difference) a package be plundered, or stolen from the ship while lying in port, he is liable, whether it be by thieves or by his own crew.

Read over your bill of lading:* you there find that when you acknowledge to

* The bill of lading is a most important document, and as the master is always a party thereto, he ought to understand it. His first duty is to grant a bill of lading to the proper person, and his second is to deliver the goods to such party as the shipper may therein direct. When goods are shipped, a receipt for the same is, in the first instance, mostly given, and subsequently a bill of lading (in triplicate, or more as the case may be) is applied for. The receipt first given must be redeemed and cancelled by the bill of lading being granted to the holder of that receipt, otherwise the master may be answerable for the bill of lading having fallen into wrong hands. Due care should be taken by the master to retain one out of the set, and he ought by a remark in the margin, when he attaches his signature, to protect himself from the liability of answering for the contents of pack-

have received a package in good order, you engage also to deliver it at its destination in like good order and condition, "the dangers of the seas excepted." By the dangers of the seas are understood, all events which no human prudence, foresight, or power can control; all acts of Almighty God, such as hurricanes, storms, lightning, and the like; other dangers, such as accidental fire, enemies, pirates, and all dangers of navigation.* Fire at sea is generally occasioned by lightning, accidental circumstances on board, or carelessness, not wilful. From loss arising therefrom, the owner is clearly exempt. But fire has been occasioned by ignition, by carrying quicklime, oil of vitriol, and such dangerous articles. If a shipowner, and the owner of goods liable to ignition, mutually agree, the one to ship, and the other to carry such goods, and loss ensue, there is no responsibility either on one side or the other. They are aware, or ought to have been, of the risk they ran, and must abide by their own acts. But the case should be different when third parties are sufferers in consequence. For instance: if, in a general ship, an owner, without giving notice to all the shippers, chooses to carry oil of vitriol, quicklime, or such dangerous articles, and the goods of any one be damaged in consequence, the owner of the ship should be liable. I have said should be: but such articles are by law and usage allowed to be carried under certain regulations; as, for instance, oil of vitriol on deck, or even in the hold, it is said, when packed in sand! Owners of ships, however, are not anxious for such freight, and generally charge an extra rate, which occasions it to be sometimes clandestinely shipped. * * * The carrying of gunpowder in large quantities is by usage also allowed; though I think it should not be, unless notice be given to all parties, more especially since the introduction of so much iron into the rigging of vessels in the shape of sheets, blocks, &c.

To return to the bill of lading. The exceptions therein have all been dictated by experience, and are meant to protect the owners of ships from liability, where loss or damage arises from causes which they cannot prevent. There is little difficulty in regard to them, and I therefore pass on to the consideration of the engagements which a shipowner does undertake, and which, it is supposed and admitted that human prudence and foresight will enable him to fulfil.

ages, of which he, of course, must be ignorant, and from weights, &c., unknown. The goods must be delivered strictly according to the directions contained in the bill of lading; strictly, because the act of shipment is deemed a delivery to the master, for and on behalf of the consignee, or person named in the bill of lading, to whom the master is then accountable. A bill of lading is similar in some degree to a promissory note, the interest therein being transferable by endorsement; such endorsement the master is bound to obey, unless good and sufficient notice be given him to the contrary. The process of a stoppage *in transitu*, or an endeavor on the part of a shipper to prevent his goods from being delivered to an insolvent consignee, is so intimately connected with a right of delivery, that it should be immediately studied. In regard to bills of lading being sent to different parties, Holt says: (ch. ii., part 3, page 375:) "It has been said, that three bills of lading are usually made and signed; and there is therefore a possibility that there may be conflicting demands upon the captain by the different holders. Nothing, however, is here required of the captain but to act in good faith, and to the best of his judgment; and to make delivery of his cargo to the person who first demands it of him, upon presentment of a bill of lading, and under circumstances which *do not justify suspicion* of such person having unfairly procured the possession of it. If he act differently, he is answerable according to the circumstances of the case, to the person injured by his negligence, the bill of lading being not only the instructions of the merchant to him, as his carrier, or servant, but his own special agreement to deliver according to its conditions."

* "If, however, a ship be driven by stress of weather on an enemy's coast, and be there captured, it is a loss by capture, and not by perils of the sea."—*Blunt*, page 202.

His duty is to deliver the goods in the same good order and condition as they were in when he took charge of them. In the first place, then, he is bound to provide a proper vessel, tight, stiff, stanch, and well and sufficiently found for the voyage. And she must not only be so at the commencement of the voyage, but must be kept so during its progress, at the owner's own proper charge. To this rule there is only one exception, and that is, when a sacrifice of any part of her is made for the benefit of all interested in the adventure: viz. to extricate them from a common danger, and then all are bound to contribute to make good the loss. This is what is termed *general average.* In all other cases, where the ship wants repair, whether it arises from injury sustained during storms, tempests, stranding, or common wear and tear, the owner must do the same at his own cost.

If from any defect in the vessel the cargo sustains loss or damage, the owner is bound to make it good; and it matters not whether that defect be unknown or otherwise, the owner is liable for the consequences. Some of the old sea regulations say, that should damage arise by rats, and the captain have taken the precaution to have cats on board, he could not be liable; but such a precaution could not protect an owner in the present day; and if water enter by a rat-hole, and damage the cargo, or if it be otherwise injured by those vermin, the owner would be liable, though he had a hundred cats on board.* This is the law of England and of France; but decisions have been made to the contrary in the courts of Louisiana.

If damage should arise from worms perforating the ship's bottom, the loss should also fall on the owner of the ship.† He should use precautions, and protect by copper the bottom of the vessel, before he undertakes to carry goods to and from places where this injury is likely to arise. If the owner of the goods were duly apprized that the ship had not this protection, then he would have no reason to complain.

Coeval with the earliest recorded adventures by sea is the regulation, that if the cargo be injured by improper stowage, the owner of the ship will indemnify the owner of the goods so injured; and so it is at the present day: and this regulation is taken from laws so old, that the actual dates are unknown.‡ This therefore shows the master the necessity for great care and attention in the stowing of the cargo. It behooves him not to be too great a man, and to trust this important duty entirely to his officers and stevedores. He is responsible, and consequently should have a watchful eye during the loading of the vessel; not only that one description of goods may not be damaged by another, as, for instance, packages of silk, by being placed under casks of oil; bales of muslins, by being stowed on salt; but that there be sufficient dunnage also. All vessels leak more or less, and therefore the cargo should be defended from contact with the bottom and sides by sufficient dunnage and chocks.

It sometimes happens that the master is placed in a very awkward situation as regards the delivery of the goods, by an effort being made by the shipper to stop them *in transitu;* that is, an effort to regain possession of them before they are

* "Si quelques marchandises sont endommagées dans le navire par les rats, faute de chat, le patron est tenu à des dédommagemens."—Consulat., art. lxvii. Vide also Cleirac, p. 215. Le Guidon. Les coutumes de la mer du Levant. *Dale* v. *Hall*, 1 Wils. 281. *Hunter* v. *Potts*, 4 Camp. 203. Also Abbott, 224.

† Vide *Rohl* v. *Parr*, 1 Esp. Rep. 44.

‡ Vide Laws of Oleron, art. xi. Le Guidon. Wisbuy, art. xxiii. Valin, Liv. 2, des Matelots, art. 1, &c.

delivered to the person to whom he has sent the bill of lading. For instance: I ship goods on board a vessel bound to New Orleans, and take four bills of lading filled up to order. One of these I send, of course, by the same vessel, and another by some other conveyance: both to a friend at that port. A few days after the ship has sailed, I hear something affecting his credit, which induces me to take steps to prevent the goods getting into his hands. I send another of the bills of lading by way of New York to another correspondent at New Orleans, with explanations and orders to demand the goods in question. On the ship's arrival, the master finds two parties claiming the same property, each having a bill of lading. What is he to do? His duty is simply to deliver the goods to the person first presenting a bill of lading therefor, after giving the other party notice that he will do so, that he may obtain possession of them by exercising his right of stoppage *in transitu*—or by otherwise proving his right to the possession of the property. In no case is it the right or duty of the master to decide between the claims of the disputants for the property, nor can he be put to the cost of an application to a legal tribunal. If the goods be not taken from him by a legal process, instituted by one of the claimants, he is justified, after reasonable notice of his intention to the other party, in delivering it to the first person who presented to him an authenticated bill of lading therefor.

## FREIGHT.*

Consequent upon a right delivery of the cargo is the payment of *freight*. The subject of freight has occupied the attention of legislators and able men in all maritime nations since very early times; it has also been much discussed in our own courts of law. The labors of the former and the records of the latter have been condensed by able writers of the present day, whose works should be perused and studied by every young master of a vessel who wishes to rise in his profession. Freight is due and payable on whatever a ship delivers at her port of destination. As security for the payment of freight, the shipowner has a lien upon the merchandise itself, and he has a right to retain the possession of all, or any portion of the goods, until the freight be paid; and this lien can only be divested by the voluntary act of the shipowner. It is no answer to a demand for freight, that part only of the cargo has been delivered; for the quantity delivered, freight must be paid, and the owner of the cargo must seek his remedy for the short delivery, according to the circumstances of the case. Neither is it an answer to a demand for freight, that the cargo is damaged. If the damage arose from a peril of the sea, the shipowner is exonerated by the terms of his bill of lading; if from his negligence, he may be compelled by an action at law to make the damage good. But there can be no set-off without consent: because the claim either for the non-delivery of a portion of the cargo, or for the damage to that portion delivered, by the negligence or want of care of the shipowner or his agents, is uncertain and unliquidated. The claim for freight, on the other hand, being certain and fixed by the contract, may be set off against the claim of the shipper for a short delivery or damage to the goods: *the freight must be paid.*

* For many valuable suggestions offered in the compilation of this portion of the work, and for the major part of the *legal* information, I am indebted to Francis H. Upton, Esq., Counsellor at Law, of this city.

Neither is an abandonment of the cargo to the shipowner a satisfaction for freight. Suppose a cargo of grain to be so much damaged by perils of the sea, as, when delivered, to be absolutely worth nothing; or, suppose the market to be in such a state that the grain is not worth the freight: is the shipowner to be compelled to take the cargo such as it is, as a compensation for the transport? Certainly not. The owner of the grain may say, I will not accept the same; but that would not cancel his agreement, and the shipowner must be paid. The latter would be in possession of a lien worth nothing, but he would still have his remedy; that is, when the parties contracting, by simple bill of lading or by charter-party, are amenable to, and within reach of the law of this country. It is easy to imagine a case where, from the consignees refusing to accept a worthless cargo, a shipowner may be left to seek a remedy abroad without much chance of redress. But it is a matter of rare occurrence that a cargo is not worth the freight, and acceptance binds for carriage. A consignee is not allowed to accept the good and refuse the bad; he must take all, or none. Able men, commentators, and others, have expressed themselves favorable to giving a merchant the power to abandon goods which could be delivered in bulk to the master for the freight, such goods having from sea-damage become worthless during the voyage; nay, even when, by a fall in the market, they have been rendered of no value: but the positive laws of refined maritime nations are opposed to them.* In the absence of any domestic decision on this point, these laws would, no doubt, guide our own courts. Suppose the damage to have arisen entirely from the negligence of the master, for want of sufficient dunnage, still the freight is due. The demand for freight and the demand for damage are separate and distinct, and must be decided upon their own merits.† There can be no set-off, but by mutual consent.

Freight can be demanded only on what is delivered; therefore if wine, oil, rum, molasses, or other liquids, leak out, or the casks break loose, and are staved, the shipowner loses his freight. The same with goods which liquify; such as sugar. If a hogshead of sugar be found to have contracted wet, and to be half empty on arrival, the freight has oozed out also.‡ This, however, is upon the supposition that bills of lading have been signed, in which it is acknowledged that the cargo has been received on board in *good order and well-conditioned*. If the packages, boxes, casks, &c., are not so received, the liability for damage may always be guarded against by expressing the fact in some manner upon the bill of lading signed; but if a *clean* bill of lading be signed, nothing will exonerate the shipowner from a delivery of the cargo, and its delivery in like *good order and condition*, but the express exceptions of the contract itself. I would remark, however, that particular agreements or usage may alter this. For instance: wine is shipped in pipes, and freight thereon is paid

* "Likewise the merchant shipper cannot abandon the merchandise before mentioned to the master for the freight, if its damage has arisen from its own tendency to spoil, or from the fall in price consequent on its arriving out of season; or from the too great supply, as in grain, wine, or salt; nevertheless as regards salt, it was formerly practised, (which is contrary to reason,) unless it had been so stipulated in the charter-party."—Le Guidon, chap. vii. art. x. Do. Négoce d'Amsterdam, ch. ix. p. 121. Valin, liv. iii., tit. iii., art. 25, says: "Merchants shall not oblige the master to accept for his freight goods fallen in price, spoiled, or damaged by their own nature, or by accident."—Do., Pardessus, Vol. II., p. 145.

† "If part of the contents of casks leak out, freight is due, although the shipowner may be in fault, and answerable in damages for his neglect."—*Blunt*, page 182.

‡ *Blunt* says, however, "Unless the leakage was caused by imperfection in the casks."

per tun or cask: if a pipe be delivered half full, if there be no fault on the part of the shipowner, the freight is due.

As a general rule, freight becomes due only when the cargo is brought to its port of destination, for then only has the shipowner performed his engagements. If, by stress of weather or other cause, a ship puts into another port and unlades, or if she is wrecked and the goods are saved, they must, at the expense of the owner of the ship, be transported to their destined port, before freight is payable. Freight *pro rata iteneris* is not due, unless the owner of the cargo agrees to receive it at a place short of its ultimate destination. What the freight should be in case of such agreement, it is sometimes difficult to determine. The old law-books say that it should be computed according to the distance of transport; but distance is not always a just mode of calculation, inasmuch as it frequently happens that the cost of forwarding the goods on from an intermediate port would be greater than the original freight, although that port be very near the one of destination. It may, however, be otherwise.

As it is the right of the shipowner to transport the goods by some other means to their port of destination to entitle himself to freight, after the disability of his own vessel, therefore whenever a negotiation takes place as to terminating the voyage short of the first engagement, the knowledge of this expense leads, or ought to lead, to an equitable compromise, and ought to prevent vexatious demands for the full amount of freight.

Where the parties, however, may have no means of communication, the master may be called upon to act as agent for all concerned. Imperious necessity may command, great advantage to the cargo may advise, that the voyage may be terminated at the place of accident: for instance, a cargo of grain, which is perishable, may be damaged; in such case, a claim for freight exists.

Freight is sometimes paid in advance, which, should the voyage not be performed, may be demanded back or retained, according to the circumstances which prevented the voyage from being completed, and the nature of the contract with the shipowner when the payment was made.

## INSURANCE.

*The interests of the insured and the insurer are so much blended and mixed together that they may be considered one and the same: so much so, that it is at least dangerous for the master of a vessel to attempt to separate them. By a confusion of ideas in this respect; by seeking for and following the advice of agents and others; by abandoning the dictates of plain, common sense, many a well-meaning master is led into measures which, as regards both ship and cargo, are sometimes most prejudicial to their respective owners. To take a case in point. A vessel having encountered a violent gale, in which she suffered severely, especially in her masts and rigging, and having sprung a-leak, was obliged to bear up for a port, where, from local circumstances, the want of competition and other causes, the proper repair of a vessel was extremely difficult, and enormously expensive. Neither vessel nor cargo was valuable. The captain, like a prudent man, wished to expend as little as possible, and as the cargo was perishable, wished to reach his destined

* Vide "Lorimer's Letters," page 59.

port without delay. He was of opinion, that, as the vessel had not been ashore, a temporary repair would be sufficient; and with such, he was confident he could have reached in safety the place whither he was bound. The surveyors reported that such and such repairs were necessary; that she must be discharged, hove down, and this, too, in a place where such an operation was hazardous, nay, almost impracticable; that she must be opened, &c.; every part of which repair, he was told, he must make, or he would be reported at Lloyd's, and his insurance would be invalidated. This terrible name of Lloyd's had its effect, and the consequence was, that a sum was expended, and a delay occasioned, which, incredible as it may appear, nearly equalled a total loss. I do not say that the adviser did not act according to the best of his judgment, or that the surveyors (though one of them was the shipcarpenter who repaired the vessel) were not conscientious; but I do say, that if the master had been more firm and decided, or had he been sole owner of the ship and cargo, and not insured at all, the loss might not have exceeded twenty per cent.; whereas, by enormous charges, fees, agencies, commission, bottomry, delay, and sale of part of the cargo, the loss was nearly total, though the vessel arrived. Far be it from me to encourage rashness or obstinacy in a master, when respectable, competent, and able men say such and such repairs are absolutely necessary before the vessel can proceed to sea, however hard it may be on all the parties interested: for the sake of those parties, his own life, and the lives of his crew, he must yield to circumstances, but his own judgment should be continually on the alert. In the case just cited, the captain could have obtained certificates from men of sufficient experience, confirmatory of his own and his crew's opinion, that a temporary repair would have enabled the vessel to proceed to her port of destination; and who will say, if he had acted on these grounds, and the vessel had been lost, that the policy would have been cancelled or vitiated? He acted according to the best of his judgment, and he is insured as well as the ship.

How frequently, by following the advice of others, is the captain induced to put an end to the voyage at an intermediate port, especially as regards the cargo! How frequently is he induced to authorize the sale of goods which might have been forwarded on to the place of destination; the sale, and the consequent sacrifice of goods with which he has been intrusted, merely as a common carrier—of goods upon which he has no demand, and which might have remained in safety until the owners of them had been consulted!

It is indispensable that you know the nature and terms of the agreement between your owner and his insurer; that you comply with that agreement; that you be honest, and in all cases of accident or emergency, act as if the property, both ship and cargo, were your own, and as if there were no such contract as that of insurance known. You need not be told, that insurance is a contract, by which for a certain sum of money, generally reduced to a per centage, and called a premium, an insurer or underwriter agrees to indemnify the party insuring against any loss or damage which the ship, or other interest insured, may sustain on the voyage contemplated. There are, of course, certain conditions to this agreement, some implied and understood, or arising out of the nature of the voyage, and others which are expressed on the face of the contract; which conditions, the captain, as the servant of the owner and his representative, is bound to perform. One of the implied conditions of every contract of insurance is, that the vessel shall be *seaworthy for the voyage*, and by this is meant not only that the vessel herself be tight and strong,

and furnished with every necessary equipment, but that she shall be well and sufficiently manned and victualled. The competency of the master for the voyage is a part of the condition of seaworthiness. By competency is understood that he must have had such experience as to justify his owner in committing the ship to his charge. The shipowner is bound to find a fit and proper person for this service; and if circumstances subsequently prove that he was not such, the shipowner must take the consequence. But incompetency can only be determined by an appeal to a jury. There is not, in this country, any court established for the examination of young men intended for the mercantile sea-service, whose certificate might be referred to before they be intrusted with the charge of a ship; but if there were, its certificate would not be admitted by our law to contradict facts, subsequently proved on oath, establishing incompetency. So, with regard to the ship, any certificate from surveyors, previously to her entering on a voyage, that she was seaworthy, &c., would not avail, if a subsequent examination proved that she could not have been so.

Not only must the master be competent, but there must be at least a second in command, his mate, who, in case of any accident befalling the master, can take his place, and conduct the adventure. In using this strong term, that there must be a person capable of taking the place of the master, should accident or circumstance require it, I speak the language of prudence only. It must be obvious that a vessel cannot be deemed properly found and seaworthy unless such an officer be provided. The importance of this qualification in a mate is too frequently overlooked. His appointment, as well as the selection of the crew, is left, by usage in this country, and by express regulation in others, to the master. It may and does often follow, then, that the professional character of one officer is an index to that of the other. An ignorant, and then, in all probability, a narrow-minded, jealous master may by accident choose an able mate; but the chances are that he appoints one of no greater attainments than himself. The situation of an adventure intrusted to such hands may be imagined.

Events may prove that a mate had that knowledge of mere practical seamanship, which would be sufficient to satisfy the implied conditions of a policy of insurance; but mere practical seamanship is not all that is requisite in either master or mate. Suppose a vessel putting into an intermediate port, requiring a great outlay, and all the care and attention and thoughtful consideration due under such trying circumstances; and suppose the master to die early after her arrival there, and the whole charge to fall on an inexperienced, incompetent mate. The consequences are too obvious to need pointing out. I could, however, furnish instances of ruinous loss to the owner and others interested, by such a state of things, and ample proof that the worst apprehensions have been realized.

The employment of an efficient crew is also necessary to a compliance with the condition of seaworthiness for the voyage. By an efficient crew, is meant a set of men sufficiently numerous, and of that age and experience necessary to the proper management of the vessel.

A pilot must also be provided wherever law or usage requires that he shall be on board; and the vessel must be well found with all tackle and apparel, anchors, cables, provisions, and water, necessary for the voyage contemplated. Here let me give you a caution. Sometimes a master, to make more room below, is induced to carry part of his stock of water on deck: this is not a secure, and consequently, not a proper place, for the first sea striking her may carry it away; and then the

putting into port for a supply would, perhaps, be considered as the consequence of the unseaworthy condition of the vessel at the commencement of the voyage, rather than the result of a sea peril.

The carrying of goods on deck, judging from the old sea laws, was occasionally practised in very remote times. The practice exists to a limited extent at the present day, although the reason for it may not be as good as formerly, considering the great improvements in the construction of our vessels. With the practice remain also the old regulations, namely, that the deck load is not, with reference to other shippers, considered as part of the adventure: if it be washed or thrown overboard, such loss concerns its owner or the master, according to the agreement or shipment. There is, however, an exception, and that is, that although contribution is not to be made for the loss of deck load thrown overboard, deck load must, if saved, contribute to any loss suffered, or charge incurred for general good. The practice prevails to no great extent at the present day, being chiefly confined to vessels in the timber trade, and it is well that it does not, for should a deck be loaded to an extent that would impede the manœuvring and proper management of the vessel, and loss be traced to such a cause, a policy of insurance might thereby become void.*

Secondly, there must be no deviation from the voyage insured; for, if there be, the policy is vitiated. It matters not whether the deviation be or be not the cause of the subsequent loss or injury; the moment it takes place the contract is at an end. Suppose a vessel be bound hence to Malta, Genoa, Leghorn, and Naples, and to be so insured, and suppose the master were to put into Lisbon without necessity, that would be a deviation. So, if he should go first to Leghorn or Naples, and return to Malta to deliver the goods taken in for that place, that would be a deviation, inasmuch as it increases the risk. Whether it did or not, he had no right to pass Malta and then return: he should have gone to each port in succession, according to the direct course. The same rule applies to a vessel coming from a coast, such as that of Brazil, where she has permission to load at port or ports. She must take them according to their *geographical situation*, as they lie in her *direct* course to her destined port. For instance: were she at Rio de Janeiro, she might call at Pernambuco, but she could not then, without deviation, return to Rio.

Any unusual delay would be deemed a deviation. For instance: if a vessel be insured to North America, out and home, for a *summer* voyage, and the owner to benefit the cargo, keep her lying there as a warehouse, and throw the risk into a *winter* voyage, this would be an injustice and a deviation.

Necessity will, however, justify deviation; or rather, that is no deviation in its technical sense, such as avoids the policy, which is the result of necessity, or is demanded upon principles of humanity. For instance: stress of weather, want of necessary repair, to render assistance to a vessel in distress, to join convoy, sickness of master and crew, or to avoid capture. A delay in or a departure from the course of the voyage to save human life, is no technical deviation; but a continuance of the delay or departure, for any time beyond that necessary for this purpose, however great the temptation, for the preservation of property however valuable, is a technical deviation, which from that moment vitiates the policy.

Thirdly, warranties must be strictly complied with. Warranties are of two kinds:

* Vide code Louis XVI., liv. iii., tit. viii., art. xii. and xiii. *Oliver* v. *Gould*, 4 B., N. C. 134. Vide also "Cotton," page 39.

those implied and understood, and those specific, or which appear on the face of the policy. The former have been noticed before, and are those which hold good between the shipowner as a common carrier, and the shipper of goods; for instance, that the ship be seaworthy, &c., and others, which you will see are a necessary part of the contract. But the warranties to which your attention is now called, are those which appear on the face of the policy; such as, that she must sail on or before a certain day; that she must sail with convoy, (according to the circumstances of the case;) that she must pursue a certain course of voyage, such as going south of Cuba, when bound to Havana; and others of a similar nature.

This part of the law of insurance it is your bounden duty to study. Study also the general nature of the policy of insurance, that you may be the better able to fulfil the terms that your owner agrees to, when he enters into the contract, but do not confuse yourself as to liabilities. Make yourself acquainted with the nature of the voyage upon which you are bound, and the terms and conditions of the policy which insures the vessel on that voyage, and honestly, and to the best of your judgment, comply with those terms, and your owner will then be safe.

It will suffice now for our present purpose to give the wording of the policy of insurance, as a concluding reference to the subject-matter of our text:—

(VESSEL.) **By the Atlantic Mutual Insurance Company.** [No. 11927.

*JOHN SMITH* ON ACCOUNT OF *THOMAS CLARK*,

In case of loss to be paid to *Henry Jones*. Does make insurance, and cause to be insured, lost or not lost, at and from *New York to San Francisco, with liberty of port or ports on the passage*, upon the body, tackle, apparel, and other furniture, of the good *Ship* called the *Sea Lion*, whereof is master for this present voyage, *Thomas Clark*, or whoever else shall go for master in the said vessel, or by whatever other name or names the said vessel, or the master thereof, is or shall be named or called.

Sum Insured
$1,000

**Beginning** the adventure upon the said vessel, tackle, apparel, &c., at and from *New York* aforesaid, and so shall continue and endure until the said vessel be safely arrived at *San Francisco* aforesaid, and until she be moored twenty and four hours in good safety. AND it shall and may be lawful for the said vessel, in her voyage, to proceed and sail to, touch and stay at, any ports or places, if thereunto obliged by stress of weather, or other unavoidable accident, without prejudice to this insurance. The said vessel, tackle, &c., hereby insured, are valued at *fifteen thousand dollars*, without any further account to be given by the assured to the assurers, or any of them, for the same.

**Touching** the adventures and perils which the said **Atlantic Mutual Insurance Company** is contented to bear, and take upon itself in this voyage, they are of the *seas, men-of-war, fires, enemies, pirates, rovers, thieves, jettisons, letters of mart and countermart, surprisals, takings at sea, arrests, restraints, and detainments of all kings, princes, or people, of what nation, condition, or quality soever, barratry of the master and mariners*, and all other perils, losses, and misfortunes, that have or shall come to the hurt, detriment, or damage of the said vessel, or any part thereof. AND in case of any loss or misfortune, it shall be lawful and necessary to and for the assured, his factors, servants, and assigns, to sue, labor, and travel for, in and about the defence, safeguard, and recovery of the said vessel, or any part thereof, without prejudice to this insurance; to the charges whereof, the said Insurance Company will contribute according to the rate and quantity of the sum herein insured; nor shall the acts of the insured or insurers, in recovering, saving, and preserving the property insured, in case of disaster, be considered a waiver or

an acceptance of an abandonment; having been paid the consideration for this insurance by the assured, or his assigns, at and after the rate of *four per cent.—to return one per cent. if the Straits of Magellan are not used, and no loss claimed.*

Premium, $40.00
Policy, 1.25
$41.25

And in case of loss, such loss to be paid in thirty days after proof of loss, and proof of interest in the said *Sea Lion*, (the amount of the Note given for the premium, if unpaid, being first deducted,) but no partial loss, or particular average shall in any case be paid, unless amounting to five per cent. PROVIDED ALWAYS, and it is hereby further agreed, That if the said assured shall have made any other assurance upon the premises aforesaid, prior in date to this policy, then the said ATLANTIC MUTUAL INSURANCE COMPANY shall be answerable only for so much as the amount of such prior assurance may be deficient towards fully covering the premises hereby assured; and the said ATLANTIC MUTUAL INSURANCE COMPANY shall return the premium upon so much of the sum by them assured, as they shall be by such prior assurance exonerated from. AND in case of any insurance upon the said premises, subsequent in date to this policy the said ATLANTIC MUTUAL INSURANCE COMPANY shall nevertheles be answerable for the full extent of the sum by them subscribed hereto without right to claim contribution from such subsequent assurers, and shall accordingly be entitled to retain the premium by them received, in the same manner as if no such subsequent assurance had been made. IT IS ALSO AGREED, That the property be warranted by the assured free from any charge, damage, or loss, which may arise in consequence of a seizure or detention, for or on account of any illicit or prohibited trade, or any trade in articles contraband of war. AND it is further agreed, That in case a total loss shall be claimed, for or on account of any damage or charge to the said vessel, the only basis of ascertaining her value, shall be her valuation in this policy; and if not valued herein, then her actual value at the time of the inception of this risk at the port to which she then belonged. AND LASTLY, it is agreed, That if the above vessel, upon a regular survey, should thereby be declared unseaworthy, by reason of her being unsound or rotten, or incapable of prosecuting her voyage on account of her being unsound or rotten, then the assurers shall not be bound to pay their subscription on this policy.

In witness whereof, the President, or Vice-President of the said Atlantic Mutual Insurance Company hath hereunto subscribed his name, and the sum insured, and caused the same to be attested by their Secretary, in New York, the tenth day of April, one thousand eight hundred and forty-nine.

If the voyage aforesaid shall have been begun, and shall have terminated before the date of this Policy, then there shall be no return of premium on account of such termination of the voyage.

In all cases of return of premium, in whole or in part, one half per cent. upon the sum insured, is to be retained by the assurers.

$1,000. *One Thousand Dollars.*

JAMES WILLIAMS, *President.*

JOHN N. QUIRK, *Secretary.*

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As an *ultimum vale* to the subject of "Responsibilities," let me give you an extract from Lorimer, in reference to the perplexing circumstances in which a master is often placed: "My advice is, if he can, he should obtain legal assistance; not second-rate, but the best the place affords. Let it be a maxim with you through life, that good law is the cheapest."

## CARGO.

We come now to a consideration of the cargo, and the manner of distributing it in the hold of the vessel, with regard to the preservation and safety of both.* As a means of avoiding many of the difficulties which would otherwise occur from an alphabetical arrangement of the various kinds of cargo, it is found most advantageous to class them simply in a miscellaneous order, without regard to any particular system of routine. We shall therefore commence with cargoes in *bulk*.

### IRON—LEAD.

This cargo, which from its great weight renders other ballast unnecessary, usually consists of bars or pigs, and is stowed thus:—The lining† of the hold should be first ceiled over with refuse boards, to keep the ends of the bars or pigs of iron from chafing the inside planking, during the rolls of the vessel, and a layer of light wood (as pine for instance) about six inches high placed on each side of the kelson, and extending between the *fore* and *mizen* masts‡ out over the bilge and floor-heads—observing that the pieces used for this purpose are laid at right angles with the seams of the bottom planking, so as to prevent the sharp edges of the bars from working down, and also to allow the water to flow to the pumps. The first spread of the cargo is then formed by placing the bars longitudinally on the dunnage, and extending them out to the wings, until the surface of the whole is brought up level with the kelson. After which, the second layer is formed by placing the bars or pigs at right angles with the first, if the breadth of the vessel will allow, or otherwise diagonally—separating them from each other by a space of about two or three inches, so as not to form a solid mass, as no vessel could bear the weight and pressure of such compact stowage upon her central sections, without inevitable destruction. The third layer is then formed by placing the bars in the opposite way, or to make an angle with the first and second; by means of which, a systematic arrangement follows in the distribution of the cargo, while at the same time a *springing* property, as it were, is imparted to the mass, which corresponds with the motions of the vessel. This process of stowing is continued until the vessel is brought down to a depth of draught consistent with safety, which in one of a single deck is usually when a bar cannot be taken down the hatchway, on account of the internal height of the cargo. In loading a double-decked ship, however, there is this difference—viz. that about an *eighth* of the iron is reserved to be stowed between-decks, in order to maintain the centre of gravity at a sufficient height, which will render the vessel stable, and easy in her rolling motions.

* The subject-matter of this article is gathered from conversations with Mr. George Mills of this city, whose high professional standing, and thorough knowledge as a practical stevedore, are the surest guarantees I can offer, for its correctness.

† The ambiguity and frequent misapplication of the term *lining*, renders a particular definition both important and necessary. It is here employed to express the *inside* planking of the ship.

‡ With a single exception, and that in the case of *salt* or *coal*, this rule for the stowage of heavy cargoes is universal. Vide TRIM, page 14, in reference to placing weight in a vessel's extremities

NOTE.—When the entire cargo consists of *lead*, dunnage is unnecessary to preserve it, as water would do it no injury. With *iron*, however, this is not the case, as considerable damage might result from rust, during a long passage; and it would be well for stowers to bear in mind that *appearances* are the guiding criterions of a *purchaser*.

## SALT—COAL.

With a cargo of salt or coal, neither ballast nor dunnage are necessary, on account of the absorbing properties and weight of the former, and the little damage done to the latter by the contact of water. Another distinction (in carrying either salt or coal) is, that the cargo below is stowed entirely fore and aft; the former, (if we throw aside the question and importance of *trim*,) because it is found rather to be an advantage to the ship than otherwise, by preserving her timbers; and the latter, (which has a specific gravity of ,750 *less* than salt,) in order to afford the carrier the advantage of the utmost capacity of his ship. The stowage is then effected thus: About *five-eighths* of the cargo* is placed in the hold, where it is closely packed, and in such a manner as to form a gradual rising in the centre, corresponding with the direction of the kelson; after which, it is secured by means of shifting plank, lashed to the stanchions, as in the case of the ballast, as described on page 52. The remaining portion of the cargo is then stowed *between*-decks, free from the sides and extremities of the vessel, and secured in like manner from shifting. The main hatches of the lower deck are thus left open, in order to replenish the deficit below as the cargo settles, from the motion of the vessel, and the centre of gravity is lowered.

NOTE.—Salt, from its tendency to moisture, should be separated by bulkheads from other goods: even crates should not be placed in contact, for the straw in which the contents are generally packed, rots, and breakage ensues.†

## MARBLE.

This, from its great weight, and the difficulty and delicacy of its stowage, can hardly be denominated a cargo by itself, as vessels seldom carry over one hundred and fifty or two hundred tons at a time; in which case other articles of merchandise are taken in to make up the deficit of freight. For readiness of transportation, and handiness of stowage, the marble is quarried in blocks, varying from three to ten tons weight, which in loading are placed as near the centre of the vessel as possible, in order to be upon the *flat* of the floor, that the major part of the strain and pressure may be borne by the central sections of timber. The blocks are usually dunnaged with layers of light wood, to keep them from the water, which is found to *stain*, and otherwise injure the texture of the stone. They are then "chocked" with bales of rags, or wood, and the balance of the cargo stowed to the best

* This division of the cargo is by no means arbitrary, for the stability of no two ships is precisely the same. Hence, in another, which is *more* stable than the one we have supposed, *three-fourths* of the cargo may be placed below, and the remainder between-decks. Nor does this system of stowing apply to all classes of vessels, for in one of a single deck, the entire cargo (as in the case of iron and lead) is placed below, without reference to any division whatever.

† Vide *Lorimer*, page 38.

advantage, both as regards its preservation, and the stability and trim of the ship. This usually consists of light country wines, oils, Tuscan goods, &c., &c.; but as we are considering marble only, the manner of distributing those articles will be found in a more remote part of our subject. One point, however, arises in this reference, to which it is necessary to allude. In vessels coming from Italy, the baskets, or "dog-houses" of oil, which are generally stowed over the marble, (in lieu of the extremities of the hold,) and dunnaged with rag-bales, not unfrequently break by the rolling of the vessel, or other causes, and result in damaging the marble, by precluding the subsequent reception of *polish*. Another consideration (and one to which stevedores and stowers are particularly directed) is, that persons employed in loading or discharging marble should not use *tobacco*, as the *stains* resulting therefrom, by affecting the appearance of the stone, influence to a very considerable extent not only the future sale of the blocks, but the toils and labors of the workman to whom the operation of *polishing* is intrusted.

## GRAIN AND FLOUR.

From the compact stowage and weight of grain, but few vessels are capable of carrying a *full* cargo. It is therefore usual (as in the case of marble) to make up the *quantum* of freight with other and lighter articles of merchandise; and as flour and bread are the most common exports of grain countries, the balance of cargo generally consists of a proportionate quantity of that which is most readily procured for shipment. Under these circumstances we have classed grain and flour under a common head.

In carrying grain in bulk, (which is here assumed to be the case,) there are points of essential practice and observance. First, to guard against its access to the pumps; second, to prevent the grain from being damaged by the action of moisture, and the generation of sweat; and, third, to preserve the even trim and stability of the ship. Indeed, when we consider the perishable nature and tendencies of grain, and the thousand and one incidental causes by which its destruction is influenced, it would seem that too many precautions could not be taken to guard the interests of all concerned in its shipment. Among the considerations of importance in the stowage of grain (and upon the observance or non-observance of which the safety of the ship and cargo mutually depends) is, that it be placed as near the centre as possible. For this purpose a portion of the floor, contained between the fore and main hatchways, should be carefully dunnaged to the height of eight or ten inches, with layers of light wood, and bins constructed over them from thin well-dried boards and joist —having the bottom and sides formed sufficiently tight to prevent the grain from working through by the motion of the vessel. These bins are then filled by means of wooden *shutes*,* up to the lower deck, and the extremities of the hold stowed with barrels of flour or bread, which should be carefully protected by dunnage from the damp lining of the vessel. In like manner, bins are constructed between-decks, immediately over those in the hold. These (which are temporarily put up like the first) are called *feeders*, and being filled with grain, are formed with a scuttle in the deck, or some such contrivance, whereby the deficit resulting from the cargo settling is constantly supplied from above, while at the same time the

* *Lorimer* says, when the hold is not full, "planks must be so placed as to prevent the grain from shifting when the vessel lies over."

stability of the vessel is preserved. The remaining portion of the lower deck is thus left clear for the reception of the flour and bread, the barrels of which are stowed bilge and cutline.

Note.—The employment of the expression "bins," in the lower hold, obviously supposes that more than one kind of grain is shipped in the vessel. If, however, her cargo should be confined to one species, as corn or wheat, for example, one bin would be sufficient.

When grain is stowed in bags or sacks, which is by far the safest and best plan, bins are not required.

"A lamentable instance of heedlessness occurred in the case of Captain Joel Price, of the schooner Firefly, which sailed from Richmond, Virginia, to Madeira, with a cargo of corn, in the year 1825. The captain had gone many voyages without serious accident, although he was in the habit of paying no attention whatever to his stowage, more than to secure it in the ordinary manner. He had never before sailed with a cargo of grain, and on this occasion had the corn thrown on board loosely, when it did not much more than half fill the vessel. For the first portion of the voyage he met with nothing more than light breezes, but when within a day's sail of Madeira, there came on a strong gale from N. N. E., which forced him to lie to. He brought the schooner to the wind under a double-reefed foresail alone, when she rode as well as any vessel could be expected to do, and shipped not a drop of water. Towards night the gale somewhat abated, and she rolled with more unsteadiness than before, but still did very well, until a heavy lurch threw her upon her beam-ends to starboard. The corn was then heard to shift bodily, the force of the movement bursting open the main hatchway. The vessel went down like a shot. This happened within hail of a small sloop from Madeira, which picked up one of the crew, (the only person saved,) and which rode out the gale in perfect security, as, indeed, a jolly-boat might have done, under proper management."

## COTTON.

Unlike the cargoes we have hitherto considered, cotton, from its extreme lightness and difficulty of compression, requires that the ship should have a certain quantity of ballast; and as a general rule, twenty-seven tons are allowed to every one hundred tons of burden. An exception to this, however, occurs, when the vessel carries a *deck-load*,* on account of the decrease of stability, resulting from an

* At a general meeting of the American Chamber of Commerce, in Liverpool, held on the 19th of October, 1841, the following resolution, as to the carrying of cotton on deck, and as to the dunnage of cotton, was passed unanimously—viz.: "It appearing that the practice of carrying cotton on deck has greatly increased, which, by making the vessel crank, almost invariably causes damage to the cargo in the bilges; and it also appearing that considerable loss and inconvenience have arisen from the improper practice of burying the lower tiers of cotton in ballast, which is often of a damp nature, thus rotting the bagging, and causing frequent disputes, instead of its being sufficiently dunnaged and stowed above dry ballast: *Resolved*, That the Chamber recommends, that in all cases of damage to cotton under deck, which, in the opinion of authorized surveyors, shall be occasioned by either of the above improper practices, the law making the ship liable for such damage be strictly enforced.

"*Resolved*, That the annexed rules for the dunnage of vessels carrying cotton from America to this port be urged upon all shipmasters:

"Six inches, *at least*, of good dunnage under the ground tier. Nine inches in the bilge. Billets of wood, of six inches, under the lower corner of the wing bales in the second tier."

elevation of the centre of gravity of the cargo; and to counteract which, it becomes necessary to augment the quantum of ballast in a proportionate ratio. Under these circumstances, the customary allowance is twenty-*eight* in lieu of twenty-seven tons, as directed above.

In the ordinary cases of carrying cotton, the ballast (unless it should be damp of itself) is deemed of sufficient protection for the bales; the stowage of which is effected thus: A layer of ballast, usually about *nine* inches in height, is first extended over the floor of the ship, and a spread of the cotton bales is formed on top, leaving a space of about two feet on each side in the wings, to be filled with ballast; after which, a second layer of bales is put in, and the remaining portion of ballast is then stowed in all the open spaces, and breakage around the pump-well, masts, stanchions, &c. &c.

## TOBACCO.

With regard to the stowage of this cargo little need be said, as its distribution in the hold is precisely similar to that of cotton, viz. that the ballast (the allowance of which, by-the-by, is somewhat less, on account of the greater weight of tobacco) is disposed among the hogsheads in the same manner, care being taken that they are duly protected from the influence of moisture, by a sufficient height of ballast on the floor-heads and wings, and by proper dunnage in the vicinity of the pump-well and masts.

Note.—"In a load of tobacco, the whole is screwed so tightly into the hold of the vessel that the barrels or hogsheads upon discharging are found to be completely flattened, and take some time to regain their original shape. This screwing, however, is resorted to principally with a view of obtaining more room in the hold; for in a *full* load of any such commodity as tobacco, there can be no danger of any shifting whatever, at least none from which inconvenience can result. There have been instances, indeed, where this method of screwing has resulted in the most lamentable consequences, arising from a cause altogether distinct from the danger attendant upon a shifting of cargo. A load of cotton, for example, tightly screwed, while in certain conditions, has been known, through the expansion of its bulk, to rend a vessel asunder at sea. There can be no doubt, either, that the same result would ensue in the case of tobacco, while undergoing its usual process of fermentation, were it not for the interstices consequent upon the rotundity of the hogsheads."—*Am. Pub.*

## STAVES.

When loading with staves, it is customary in vessels of over two hundred and fifty tons burden to place about twenty tons of ballast; and so on in the same ratio. This is stowed fore and aft in the usual way for ballast, and a level surface then made with the staves over the floor, upon which the layers are formed, by placing the staves edgewise in the direction of the kelson, or fore and aft; after which they are wedged in tight by means of a *lignum-vitæ* mall, and the process of stowing continued until the vessel is full.

Deck-loads are often carried, in which case, however, the staves are not wedged, on account of their tendency to swell, from being exposed to dampness and wet, and the consequent liability to separate the top-timbers and upper stanchions.

NOTE.—If any portion of the staves are in a green or undried state, they should be stowed *first*, as being of more weight than when seasoned. As this consideration might be very naturally overlooked by the shipper, a *hint* to deliver the green staves first would not be altogether amiss.

## LIME.

The carrying of lime is limited chiefly to small vessels, and to those of the coasting trade. It is nevertheless regarded as a dangerous cargo, as being generally in an unslaked state, in which if it be moistened with water it instantly swells, and becomes exceedingly hot. Ballast is not necessary; but great care should be taken in dunnaging—say, at least a *foot* on the floor-heads, and three or four inches in the wings; the barrels are then stowed, as in the case of flour, to the best advantage.

## LUMBER.

When a vessel is loaded entirely with lumber, she requires a certain quantity of ballast—about the same proportion as in the carrying of "staves." The plank are stowed on the flat side, (so as to form a horizontal surface,) up to within a few feet of the deck, or at least so far as to admit of a plank going down the hatchway; whereupon the stowage is changed to the wings, which are then filled up to the deck, and the "breakage" of the hatch stowed with barrels of flour, staves, or shingles. In carrying any quantity of the latter, with a long voyage, and a good freight in perspective, it is essential to make the best stowage possible; in which case, towards the latter part of the vessel's loading, the bundles are opened, and the shingles placed in singly. Under other circumstances than these, however, the trouble of putting the bundles together again, (after the vessel's arrival, since the master is obliged by the conditions of his bill of lading to deliver in the same good order as received,) hardly balances the advantage of such compact stowage.

## HAY.

This is even lighter than cotton, and as such, necessarily requires a full amount of ballast. Dunnage is also requisite, in order to protect the bales from moisture in the wings. On the floor, the ballast of itself generally serves this purpose, with the addition of a few strips of plank, in case it should be damp. The bales, nevertheless, must be dunnaged with boards in the wings, for when a ship is thus light, she is of course less stable than at any other time, and the disposition to blow through the ceiling proportionally increased. Full cargoes of hay, however, are seldom carried on sea-voyages; and in ships going south to home ports, as New Orleans, for example, "in ballast," it is customary to take in a few hundred bales on what is termed "speculation," rather than as freight. This then serves the purpose of keeping the ballast steady, without the necessity of shifting-plank—the bales being simply stowed by hand, in lieu of being screwed in as in the case of cotton and such like cargoes, on account of the frailty of the strapping, which would be unable to resist the excessive pressure of a jack-screw, or camel. In this view of the case, and when we consider the perishable nature of hay, it is easy to perceive that a full cargo would pay but a trifling freight.

## TAR—TURPENTINE.

In the stowage of tar and turpentine, (a full cargo of either of which is seldom carried,) neither ballast* nor dunnage is requisite, except a sprinkling of sawdust over the skin and ceiling of the hold to prevent the leakage of the barrels from obtaining access to the pumps, which should receive great attention in the transportation of this species of cargo, on account of their liability to become choked. If the cargo consist of tar and turpentine in equal proportions, the former should be stowed in the extremities of the vessel, in order to avoid, in some measure, the *pressure* which would be upon it, if stowed in the centre, while at the same time it is more remote from the pumps. The barrels are then placed at each side of the kelson, in the centre of the hold, and so continued out to the wings, being stowed *bilge and cutline* with each other, and having small billets of wood between, in order to prevent their working, from the rolls and pitching of the vessel. This, which constitutes the ground tier, or first layer of barrels, should be carefully and thoroughly besprinkled with sawdust, moistened with water, and the riding tiers then stowed in a similar manner.

NOTE.—On board of vessels going to Europe, and such others as carry a full cargo, it is the custom to have a quantity of turpentine always in readiness to throw down the pumps in case of their becoming choked, as being the only available substance by which the tar can be dissolved. This is of particular importance on board of large vessels, on account of the pressure upon the ground tier, which is very great.

## SLATE.

This cargo, (obviating, from its great weight, the necessity for ballast,) though not perishable in itself, requires to be carefully stowed on account of the injury calculated to result to the vessel by the upper tiers of slate working themselves down, and wedging the sides asunder.† The floor (between the fore and mizen masts) should be first carefully levelled off by placing refuse wood or boards down until the surface of the whole is brought up even, in order to make the succeeding tiers of slate horizontal and regular. Upon this layer the first tier is formed by stowing the slate on its edge, and continued so out to the wings; after which, strips of lathing, or handfuls of straw, are laid athwart each layer, at equal distances apart, in order to keep the upper tiers from being wedged down by the pressure above, and the second layer then stowed like the first. The process is thus continued, until the whole amount has been taken on board, observing the same rule of stowage as in the case of "salt," to preserve the stability and trim.

* An exception to this rule arises in the case of large vessels loading with tar or turpentine alone, or where there is but a small proportion of the former. They then require a certain amount of ballast, (about thirty tons to every five hundred of burden,) to render them sufficiently stable, on account of the comparative elevation of the centre of gravity, which arises from the continued stowage of the same article throughout, in lieu of "topping off" with a lighter substance. This quantity of ballast should be distributed among the first tier of barrels in such a manner as not to interfere with the sailing of the ship, by the destruction of her trim.

† An illustration of this is not unfrequently seen in the bursting of the sides of a cart loaded with slate, where the precaution of separating the layers by bits of lath has been neglected.

NOTE.—The term cargo here, is not designed to convey the idea of a *ship-load:* first, because a vessel could not carry herself *full;* and, second, on account of the introduction of *tin* roofs, and such like substitutes for slate, which have tended, in a great measure, to diminish the demand. It is therefore usually shipped rather "in lots to suit purchasers," than to supply a particular market of rapid and constant sales.

### FRENCH GOODS.

With cargoes of so much value, great pains are necessary in the stowage; and the dunnage should be at least twelve or fourteen inches high over the floor-heads. The goods, which are generally packed in cases, should be stowed in the after part of the vessel, free from the wings, masts, pump-well, &c., and indeed protected at every point, from a contact with which they are liable to the damage of moisture, taking care that the distribution of weight is such that the trim of the vessel may not be destroyed. It sometimes happens in the shipment of this cargo that baskets of champagne and other light wines are included. These, from being of less value, and less liable to damage, are placed separate by themselves, so as to prevent the liability of leakage upon silks, laces, &c.; but it must be remembered, that every stain upon the exterior surface of a cask or case tends more or less to affect its sale. Nor must it be forgotten, that ballast is also necessary. Vessels coming from French ports, therefore, carry a sufficiency of *buhr-stone,* in order to avoid, in some measure, the expense of extra ballast, which, while it serves to keep them steady, answers the purpose of protecting the goods from moisture and dampness.

### TEAS, &c.

This cargo, like many others of a light and delicate nature, requires a certain amount of ballast with it, to render the ship sufficiently stable for the performance of a voyage so long and varied as one from the Indies. About three-fourths of the whole quantity of ballast is first levelled down on the bottom of the vessel *fore and aft,* and boards then placed over it for the reception of the cargo. Strips of bamboo should also be nailed up and down the side-lining, and over the deck, to preserve the tea-boxes from the influence of chafe, and from damage by leakage; after which, the cargo is placed in tiers over the hold fore and aft, leaving the wings clear, in which is stowed the remaining fourth of the ballast, or mats of cassia; for it sometimes happens that this portion of the ballast is required to trim the ship either forward or aft, in which case the wings should be filled with something else.

If a portion of the cargo should consist of crapes and silks, it is usual to select the most dry and secure place in the hold for their stowage; as, for instance, between the fore and main hatches. This is called the "silk room," and is formed by boxes of tea on each side.

### SUGAR.

Ballast is unnecessary in the transportation of this cargo. This may be accounted for from the great weight of sugar, and the fact of the trade being confined chiefly to small vessels. The dunnage, however, should be placed with more than ordinary

care, for if the hogsheads are brought in contact with water, their contents become sensibly diminished, and the carrier loses a proportionate share of his freight.* In low-decked vessels, where the height is limited, and where it is desirable to get two or three heights in the stowage, there is frequently a diminution of dunnage, and in some instances *none at all;* but this is done at the master's own risk. Sometimes, too, the ground tier consists of molasses, which is carried in order to avoid the use of dunnage, whereby a considerable degree of room is obtained. As for instance: a vessel in ordinary cases stowing but two heights and a half, might, under this arrangement of her cargo, carry three.

When the entire shipment consists of sugar, the hogsheads of the ground tier are placed fore and aft, and as closely together as circumstances will admit—the dunnage being first carefully laid to the height of at least eight inches in the bilges, with strips of board up and down the ceiling; after which, every hogshead is duly bedded and chocked with billets of wood, and the riding tiers stowed in the same manner.

Not unfrequently where a third height cannot be had, it is usual to make up the balance of cargo with *boxes* of sugar. This, however, must depend upon the manner in which the sugar is shipped from the port at which the vessel loads.

## MOLASSES.

The carrying of this cargo, like that we have just considered, is confined to small vessels. No dunnage, however, is necessary, except beds and chocks to keep the bilges of the casks free. But care must be taken in the stowage in order to economize room, or, in technical parlance, to avoid "falling short in the longers." The ground tier should be laid straight fore and aft, at each side of the kelson, and the heads of the casks separated by a space of about an inch. This is done to save the length in the second and third tiers. In placing the ground tier, the "breakage" caused by the masts is omitted and filled with wood, so as to avoid "crossing the heads" of the casks, each of which should be carefully bedded and chocked, to keep them from working. The first tier of riders is then stowed in the same manner, observing that the casks rest fair upon those of the ground tier, so as not to have the entire weight sustained at any one point. The casks of the third or last tier (since *four* heights are never taken) are placed in empty; then bedded and chocked, and finally filled by means of a leathern hose. Deck-loads are often carried by vessels in this trade. These, seldom exceeding sixty casks, are bedded and chocked, as already described.

Note.—It may not be amiss to call the general reader's attention to a distinguishing feature in the build of vessels destined for the West India trade, and known commonly as "molasses drogers." This consists in the strength which is given to the upper works, in order to enable them to carry deck-loads. For this purpose the top-frame and stanchions are brought up without any diminution in size or thickness, and, in addition to the usual fastenings, kept from separating by massive iron rods extending entirely athwart the vessel, and keyed at each side.

* This of course depends upon the agreement, and supposes that the cargo is carried by the *hundred weight* and not by the *hogshead.*

## GUANO.

Prior to the reception of the cargo, the lining of the vessel should be carefully ceiled over with refuse boards to prevent it from being injured by the heat of the guano, which is oftentimes very great. Ballast is unnecessary; and the cargo is stowed between the fore and mizen masts in bulk, without other protection than that already described. Towards the latter part of the stowage a gradual rising is formed in the centre as with salt or coal; and when brought up within three or four feet of the lower deck, it is secured by shifting-planks lashed to the stanchions. After which, the guano is again thrown down until the hold is filled, and the "between-decks" stowed in a similar manner, where it is also kept from shifting by proper means and precautions. As a *finale*, the lower hatches are left open in order to replenish the cargo as it settles, and at the same time to supply it with air, as the temperature of a ship's hold, under these circumstances, is often excessive.

Note.—In the stowage of guano, there is one point which must not be overlooked—viz., the well should be carefully protected with old sails, or some such preventive, whereby the pumps may be kept clear.

## PEPPER.

With medium-sized vessels,* which are mostly employed in this trade, about one hundred and twenty-five or thirty tons of ballast are necessary. This should be stowed fore and aft, and closely planked over, to prevent the pepper from working down. No dunnage is requisite, as the cargo is not liable to be injured from contact with water. It is therefore stowed in bulk, to the best advantage, in every available part of the ship, except the cabin and forecastle; and all the empty casks, bags, &c., &c., filled, in order to make up the deficiency in the hold, which is caused by the pepper *shrinking* as it becomes dry. In vessels of two decks, however, it is customary to remove one or two of the planks from each side over the hold, that this deficiency may be supplied of itself, and when necessary, as the vessel rolls.

## WHALEBONE.

In the stowage of whalebone, (a full cargo of which, by-the-by, is never carried,) it matters not in what part of the ship it may be placed, provided it be perfectly free from wet. For this purpose it is usual to distribute it among the other cargo in places of broken stowage, but always clear of the wings, and such other points where it may be liable to the influence of moisture and dampness.

Note.—On board of whale-ships, a place is always selected for the stowage of whalebone, and great care taken to keep it perfectly dry.

## FRUITS.

From the perishable tendencies of fruit, and the distance of carriage, small vessels are mostly employed for the trade. Before receiving it on board, however, it is usual

* About three hundred and fifty tons burden.

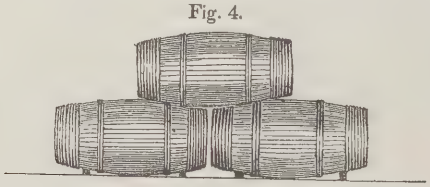
to take in a sufficient quantity of *brimstone*, as ballast. This is stowed on the bare floor, without the protection of dunnage, as water is not known to injure it. Over this, strips of board are laid, and the boxes of green fruit* then placed in tiers, so as to be as near the centre of the vessel, and the vicinity of the hatches, as possible. These tiers are generally separated from each other in the middle, by a space about two feet square for the circulation of air; after which, they are brought up to within ten inches or a foot of the deck-beams, so as to admit of the hold being freely ventilated. The balance of the cargo (which usually consists of a proportionate quantity of almonds, walnuts, filberts, prunes, and dried fruits) is then stowed in the extremities, (in boxes and bags,) as being less liable than any thing else to damage, from the effects of dampness and the want of air.

NOTE.—The hatches of vessels in the fruit trade are in general temporarily built up to the height of three or four feet above the combings, and fitted with lids, in order to admit of the circulation of air. At sea these are opened whenever the weather will justify, and windsails placed down, for the purpose of cooling the fruit, and dissipating the moisture and humidity which is constantly generated.

## WINES AND BRANDIES.

In the shipment of wines and brandies, although neither ballast nor dunnage is necessary, (except a quarter-bed under each end of the cask, to keep the bilge free from the bottom of the ship,) great care must be observed in the stowage. This is effected by commencing in the centre of the vessel, immediately under the main hatches, and working both forward and aft, and out to the wings—stowing the larger casks first, and placing them *bilge and quarter* with each other, thus:

Fig. 4.



By this means great economy is made in the stowage of the ship, and at the same time a perfect and compact system maintained throughout.

NOTE.—This supposes a uniformity in the casks, and the case of a small vessel, where the entire cargo consists of wines and brandies. In loading a large vessel, the balance of the shipment is usually made up with boxes of claret, cordials, &c. These are placed on top of the brandies, which are seldom stowed in more than two heights.

## HEMP.

In loading a vessel with hemp from Russia, (which we will suppose to be the case,) it is customary, before taking on board the cargo, to put in a sufficient quantity of bar-*iron*, as ballast for the ship, having it stowed on layers of light wood,

* If a part of the cargo should consist of *lemons*, it is usual to place them lowest in the vessel, as being of more weight than oranges.

(as pine for instance,) which are extended over the floor, at a height sufficiently ample to protect the iron from rust. After which, the iron is carefully covered with mats to prevent injury to the bales, and a layer of hemp then placed in the vessel fore and aft. This (if the vessel should exceed six hundred tons burden) is covered in turn with mats, and a spread of iron, and again surmounted by a layer of hemp, as at first. This process of stowing is continued until the interior height of the cargo nearly reaches the beams of the lower deck, when the mass is compressed by means of jackscrews and camels.

NOTE.—If the cargo should at the same time consist of *duck* and *diaper*, or *sheetings*, the same rule should be observed in their stowage as in the case of crapes and silks from the East Indies.

## LOGWOOD—MAHOGANY.

With regard to the stowage of this cargo, a few words will suffice, as the carrying of it is limited chiefly to vessels of light draught, and the distribution is the same as in the case of "Lumber" already described. Dunnage is unnecessary, in order to preserve it, as water is not known to injure it to an extent which might justify the expense and care of such protection.

## COFFEE—HIDES.

In the stowage of this cargo, ballast is unessential. If the vessel load at a West Indian port, and the shipment consist of coffee alone, it is the practice to place about eight or ten inches of logwood in the bottom as dunnage, which is carefully covered with mats, or old sails, and the coffee-bags then stowed fore and aft to the best advantage—being protected in the wings by an ample allowance of dunnage also. If at Rio de Janeiro, and where the cargo then consists of coffee and hides in equal quantities, in lieu of logwood, rosewood (if it can be obtained) is generally used for dunnage. This is arranged in the vessel, as described above, and the hides placed in layers of ten or fifteen, as the case may be, over the dunnage; and also up and down the sides, *over* the dunnage of the wings. This is done on account of affording the best stowage, by pressing the hides down from the weight above, and in order not only to save the coffee from injury by dampness, but in case the lower layers of bags should burst and break loose. Where, however, the cargo consists entirely of hides, there should be at least eight or nine inches of (*level*) dunnage in the bottom, and two or three inches in the wings, with a single spread of hides nailed up and down to keep the dunnage in its place. The stowage is then as follows: The hides are first folded longitudinally in the centre, and placed in layers *athwart* the vessel, in such a manner, that each hide shall lap the other by about three inches from the fold, in lieu of being stowed directly one above the other. This is done to preserve the layers horizontal, as a considerable difference is found between the thickness of the hide at the centre and at the extremities. This process of stowing is continued until the layers are brought up to within about four feet of the deck, when the hides are placed in, evenly upon the top of each other, "back and belly," to within two feet or so of the deck. At which point a hide is partly left out in the layer, for the purpose of what is technically termed "booking," and the balance of the space filled up, as at first, to the beams. Finally, some fifteen

or twenty hides are laid within each other in the "book," (or the one already left out,) and the whole closely pressed in between the last layers, by means of an oaken slice, and a dog and tackle.

### ICE.

In loading with a cargo of ice, a sufficient quantity of ballast must be taken in, and levelled down fore and aft as smoothly as possible. Upon the top of this, a layer of ice is placed, and covered with a thorough sprinkling of rice-chaff, or some such material, which should be closely pressed down into all the interstices, in order to make the stowage compact, and to exclude the air. In this manner, the succeeding layers are placed, until the hold is full, observing at the conclusion of the stowage that the bulkheads and hatches are as tight as possible, to prevent the admission of external and heated air.

NOTE.—The term "sufficient ballast" is employed to cover the circumstances of the case—viz. the length of the passage, the season of the year, and the distance of the port of destination. In view, then, of these considerations, the quantity must depend upon the judgment of the stower—for should the ice melt to any extent, during the voyage, the stability of the vessel would be diminished in such a ratio as probably to force her to an entrance into an intermediate port in distress.

N. B.—In loading with ice, it is customary to have a person from the ice-house, to assist and superintend the stowage.

### LARD.

This is usually shipped in small quantities, in kegs, in vessels freighting with provisions, where it is stowed to fill up breakage, and spaces which will not admit a barrel. This, however, should *not* be done, as by mixing it thus indiscriminately with heavier articles of cargo, the pressure upon the kegs is often such as to force out the heads. The safest place for lard is to stow it apart by itself in the after peak of the ship. If, however, circumstances will not justify this arrangement of it, care should be taken not to stow it over cotton, flour, or Indian meal, or to subject it to any undue pressure.

### BEEF—PORK.

In the stowage of this cargo neither ballast nor dunnage is necessary, if we except beds and quoins to prevent the barrels from working. These are placed upon the bare skin, bilge and cutline with each other, and carefully chocked. It matters but little which article of freight is stowed first, as the barrels are generally of equal weight—the only important precaution being that of preserving the trim of the ship; for this purpose, it is essential that the bulk of the cargo should be in the centre.

### ROSIN—PITCH.

Vide TURPENTINE.

No dunnage is necessary whatever, and the barrels are simply stowed without reference to any other protection than that of chocks, to keep them from working loose at sea.

### WHALE-OIL.

If in a large vessel, (as one of *three hundred and fifty tons,*) where a full cargo of oil is carried, about *thirty tons* of ballast are necessary. This is first stowed in the usual way—viz. fore and aft, and levelled down flat. As the oil is generally shipped in casks varying from *forty* to *two hundred and seventy-five* gallons, great care must be taken to economize room, and make good stowage; since it is evident that the casks will not admit of being stowed either bilge and quarter, or bilge and cutline. For this reason, the larger ones are placed in the vessel first, and the hold topped off with casks of a lesser gauge, observing to bed and chock each one in such a manner as to preclude the possibility of any getting loose at sea. No other dunnage is necessary, as the casks are generally so saturated with oil as to counteract every injurious tendency of dampness or wet.

NOTE.—Where the cargo consists only in part of oil, the oil should be stowed first, and the balance of the freight carefully dunnaged and chocked on top.

### RICE.

This cargo, though requiring no ballast in the ship, is, nevertheless, of such a delicate and perishable nature, that particular pains must be taken to protect it by a sufficiency of dunnage. For this purpose there should be at least eight or nine inches of solid bedding in the bilges, and strips of board up and down the sides of the vessel. The tierces are then stowed bilge and cutline, and carefully chocked.

### GOATSKINS.

These, which seldom constitute an entire cargo, should be stowed in some convenient part of the hold, free from the influences of moisture and dampness—observing to protect them by sufficient layers of dunnage, and in *all* cases to place the bales with the *flat* side towards the point from whence injury by wet is anticipated. To show the importance of this precaution, the following case is cited from the journals of the Port-Warden's office: A schooner arrived at New York from Vera Cruz, having on board a light cargo, consisting in part of several hundred bales of goatskins. These, from being stowed upon their *edges,* (or with the *folds* of the skins *down,*) in immediate contact with a quantity of *damp* ballast, were found, on opening the hold, to be damaged to such an extent as to render the major part of the shipment entirely worthless—every skin, in the bales so placed, being rotted through and through in the central fold. From this it is easy to see, that had the bales been stowed with the flat side down, a single skin in each would, in all probability, have covered the extent of the injury.

### LIVERPOOL CARGO.

This in general consists of a varied assortment of goods and merchandise, and such as constitutes the freight of a packet ship. At certain seasons of the year, as the fall for example, when the demand for *coal* is greater than at others, it is usual first to take in about a hundred and fifty or two hundred tons, which is stowed level

fore and aft in the bottom of the vessel. After this, a proportionate quantity of *pig* or *bar-iron* is received on board, and placed on top of the coal, in such a manner as to preserve the trim and stability, having strips of board laid at intervals underneath, to prevent the iron from working down and burying itself in the coal. This arrangement must of course depend upon the circumstances of the case, and the kind of freight which is offered for shipment. Sometimes the cargo consists in part of crates and hogsheads of *crockery*. These are stowed in the wings fore and aft, and carefully protected by dunnage, in order to avoid stains and breakage. In the after hold, (that is, all that part of the vessel abaft the after-hatch,) articles of particular value, such as *cloths, laces, mouslin de laines*, and other *drygoods*, are stowed. These are in like manner protected by plenty of dunnage and chocks, not only against damage by leakage and wet, but to prevent *chafe*, as it frequently happens that this species of injury is even worse than any other. In the fore hold, and the forward part of the ship, stow the "rough freight," such as crates and hogsheads of *stone* and *earthenware*, observing, however, to chock and dunnage all safely and securely. If the cargo should at the same time consist in part of *sacks of salt*, (as is sometimes the case,) place them in the main hold, and as near the vessel's centre as possible, so as to keep her in trim—having an ample allowance of dunnage underneath, and in the wings, as also mats, or some such material, carefully wrapped around the stanchions, to prevent the sacks from being stained, on account of the depreciation in value resulting therefrom; and when we consider the fact, that a contact with the most trivial article, even for a limited period, is liable to leave a mark upon the sack, this consideration becomes obviously essential.

Note.—If the vessel should at the same time carry passengers between-decks, particular pains must be taken to have the lower hatches perfectly tight, to shut out dampness and filth. And in stowing water and provisions for a full complement of passengers, care should be observed to place them in some convenient part of the hold, where the cargo may not be damaged by leakage.

## NEW ORLEANS CARGO.

This, as with a cargo from Liverpool, consists in most cases of a general assortment of goods, which are stowed in different parts of the ship, prepared for their reception—observing, however, if a heavy freight is not offered, to take in first a sufficiency of ballast, which should be stowed fore and aft, and levelled down square. If liquids, as oil, cider, brandies, vinegar, &c., form a part of the cargo, it is usual to appropriate the after hold for their stowage—placing them on the ballast, where they should be properly bedded and chocked. Over these, again, stow bales and cases of drygoods, protecting them in like manner by the requisite quantity of dunnage.

In the main hold, stow all such articles as hardware, &c., in order to keep the major part of the weight in the centre of the vessel, taking such precautions as may be necessary to prevent leakage and damage. In the fore hold, or all forward, place the rough freight, such as hogsheads of light hardware, crates of crockery, casks of oil, &c., &c., chocking and dunnaging in a proper manner.

This is simply a general outline of the stowage and distribution of a southern cargo; it will, however, serve in the case of such other articles of freight, as may be packed and shipped in a similar way.

NOTE.—It may not be altogether out of place to call the attention of the master, or mate, in the reception of a general cargo, to the necessity of noting which (if any) of the cases, &c., are marked "this side up," and see that they are stowed accordingly. This is an important point, and should not be omitted—inasmuch as it involves to a very considerable extent the responsibility of the master.

## POTATOES—APPLES.

In shipping any quantity of potatoes or apples, the barrels in which they are put up should be first perforated with holes for the admission of air, and also for the purpose of letting out water, in the event of the barrels getting wet. They are then stowed between-decks, and as near the hatches as possible, in order to have the benefit of air. Dunnage is therefore unnecessary, except a few chocks to keep the barrels (which are generally placed bilge and cutline with each other) from working at sea.

On board of vessels carrying apples to distant ports, as Liverpool for example, it is frequently the practice to stow them on deck.

## WOOL.

As the shipments of wool to this country are small, and the weight but little, it is generally stowed uppermost in the cargo, and as near the vicinity of the hatches as circumstances will admit, being protected by an ample allowance of dunnage in the wings.

A wool cargo, though not offensive to the olfactories, is perhaps more detrimental to the health of the ship's crew; and has sometimes proved dangerous from its liability to spontaneous ignition when stowed in a damp state. It is *vulgo* a "sweating" cargo. The steam which arises from its exudation finds its way through the interstices of the bulkhead into the men's berths, the air of which is like that of an oven kept humid by the sprinkling of water.* Let us for a moment conceive the effect that would arise from such a process on even the strongest constitution. Think of a man, after sleeping with his pores opened, in a "steam bath," as we may call the air of the forecastle in such a state, being suddenly obliged (as is constantly the case) to spring up into the air at a temperature near to, or below the freezing-point, (in the Southern Ocean for instance,) and proceed aloft in a sleet, or snow or hail shower, with a strong wind rapidly evaporating the moisture of his body, and leaving him scarcely half his muscular power to fulfil the tough duty of reefing or furling a frozen sail!

## RUM.

Vide WINES and BRANDIES.

## COPPER.

Vide LEAD.

* The remedy appears to be easy. "Wooden flues would carry off the steam into the atmospheric air, and prevent it from affecting any person on board the vessel."—*Naut. Mag.* Vide page 23, for a system of *ventilation.*

### MACHINERY—BOILERS, &c.

In shipping machinery, all that can be taken down the hatchways should be placed in the vessel prior to any other part of the cargo, on account of its great weight, (which ought of course to be *lowest* in the stowage,) and to afford the opportunity of securing the several pieces properly. This is done by means of beds and chocks made for the purpose. Such articles, as *cog-wheels*, and castings of a similar shape, should be lashed *vertically*, or edgewise, to the masts or stanchions—taking care subsequently to chock them on each side with bales or cases of goods. Where a *boiler*, or such like article, is carried, it should be placed on deck in beds and chocks, resting upon the beams, and as near the centre as circumstances will admit. If two are shipped, however, they are generally secured on opposite sides of the deck, by means of lashings to the ring-bolts, and by cross-lashings to each other.

### IN BALLAST.

In preparing a vessel for a distant port "in ballast," the following method should be observed in the stowage: About one-half of the whole quantity is first stowed level in the bottom of the vessel, between the fore and mizen masts; after which, the water-casks are struck down in the hold, and stowed either under the forward, or after hatch, (as may be most convenient,) where they are carefully bedded and chocked on the top of the ballast. Shifting-planks are then placed fore and aft in the body of the vessel, and lashed on both sides to the stanchions. These, which are laid edgewise, generally extend for two or three heights, at the distance of a couple of inches apart. Subsequently the remaining portion of the ballast is levelled down on each side, square with the shifting-planks, and to form a gradual rising from the forward and after parts, to the centre of the vessel.

---

As a *finale* to the subject of "cargo," the attention of the master and the mate is especially called to the necessity of *greater* care in the stowage of an ordinarily-built ship than in another which stands (in technical contradistinction) "A. 1;" as in many answering the latter description, if the cargo be properly secured from shifting and from chafe, few other precautions are essential to its preservation. This, however, is not the case with vessels which have passed the meridian of durability; and often a forgetfulness of the fact is most prejudicial to the interests of both owner and shipper—for it must be borne in mind that *ships* have reputations as well as *men*, and when once the stigma of universal damage to the cargo is fixed upon them, even years of subsequent toil and care are insufficient to remove it. Nor is this the only consideration. In reviewing the rules of stowage, which I have endeavored to lay down for your guidance, it will be seen that frequent reference is made to the subject of "dunnage." This (however imperfectly) has been done that the necessity for its *proper* application might be the more indelibly fixed upon the mind, inasmuch as the damage to a cargo more frequently arises from the neglect of the stower to place it where it *ought* to be, than from the want of sufficient dunnage in the ship.

## STOWAGE OF HOLD AND SPIRIT-ROOM.

At the original outfit of the vessel, and since the introduction of iron tanks, it is usual to construct a complete set, which are made to correspond with the shape of the hold. After having stowed the ballast, as described on page 15, these tanks are carefully placed according to their marks upon the top of the ballast, in such a manner as to form an even and horizontal surface—at the conclusion of which the seams are chocked with thin wedges of wood, and caulked to prevent the admission of dirt, &c., from above. Having thus stowed the tanks, fill them with water, and see that the lid-sockets are properly lined with *fear-nought*, or some such material, which will preclude the escape of their contents. Now commence placing the riding tier of casks upon the top of the tanks, in the space contained between the forward part of the cable-tier and the after part of the fore hatch—being careful that the gauges correspond on each side, and that they are stowed bung up and bilge free. If the heads should not match, it will be necessary to fit chime-pieces between them, and to have them well bedded, and chocked in the cutlines. In this way every succeeding row is placed until the spread reaches the wings—observing to fill up the breakage and spaces under and between, with barked wood, and to stow the smaller casks outside. Having done this, level all off with wood, and place the *pork* on the *port* side, and the *beef* on the *starboard*, and the *dry* provisions in the main hold, (over the wet,) just forward of the cable-tier, chocking all with billets of *dry* barked wood. Stow the naval stores, such as tar, pitch, lime, coal, sand, holy-stones, &c., in the breakage of the fore hold, where should be stowed also spare water-breakers, buoys, gang-casks, buckets, &c., taking the precaution always to place the heavier articles lowest, and as near the centre of the vessel as possible. Prior to all this, however, battens should be nailed to the beams of the lower deck for the stowage of oars, planks, boards, and all such necessary outfit stores—appropriating the battens in the fore hold for bar-iron, spare rammers, sponges, ladles, &c., &c.; and the space between the after bulkhead and the mainmast for gun-carriages, trucks, spare caps, and such other articles of "fitted furniture" as may be allowed for the use of the ship.

In transporting the cables to the ship, if she be lying in the stream, (as we have supposed,) they should be coiled on the deck of the anchor-hoy, in the same manner in which they are intended to be bitted and coiled in the ship. The lighter is then brought under the starboard bow, (if the starboard cable,) and the sides and sill of the bridle-port are carefully protected by mats; after which the cable is roused on board (best) by means of the messenger and capstan—the *under* end being simply brought to, with a couple of nippers, or selvagees, and *faked* along the deck, for marking, which is generally done with a turk's-head, worked under the strands, at every fifteen fathoms. See that the tiers are clear, and pass the end down the main-hatch, forming an *outside* clinch around the mainmast,* and coiling the cable away with the sun, in the

* Many years ago, on board of the sloop-of-war "Boston," in the *gala* days of hempen cables, in lieu of clinching the ends below, there were three cables spliced together, and the bight placed abaft the mainmast, which afforded the advantage of veering the scope of a cable and a half on each of the sheets

tier opposite the side upon which it bitts, careful not to break too many fakes in the sheeves, nor lay them out at the hatch, as that part of the tier should be as low as possible. When the end comes clear, point it, and get the other cable in, in the same manner, coiling it on the side directly opposite.

Within the sheeves of the tiers, coil the stream cable, hawsers, messenger, nippers, fish-tackles, &c., &c., in such a manner as to admit of immediate use, and the ends of the hawsers so that all may be passed up at once if necessary.

Note.—Within a brief period hemp-cables have almost entirely disappeared from the naval service, and in most of the vessels now fitted out, chain has been substituted for both bowers and sheets. If, however, one of the sheets should be hemp, (as is sometimes the case,) this may be coiled, as directed, on the starboard side, and the opposite space to port appropriated for the stowage of hawsers, &c.

Finally—stow the round shot and grape in their respective lockers, and arrange the casks of the spirit-room. This is done by following the general directions given for the stowage of the riding-tier in the hold—*id est*, placing the larger and heavier casks in the centre, and tapering off towards the wings with those of a lesser gauge. All are then carefully bedded and chocked, and the cutlines filled with barked wood. As the consideration of *trim* must not, however, be neglected, great pains should be taken to distribute the weight in such a manner that the "sit" of the vessel may be controlled without breaking out the hold, or changing the original stowage. For this reason, the forward casks of the kelson tier should be used for molasses, as being heavier, and nearer the centre of gravity, the after ones for vinegar, as lighter, and the central and wing casks for whiskey. Stow the sugar and tobacco forward also; candles, cheese, and soap in the wings; and tea abaft—filling up all the open spaces and breakage with wood.

# SHORT RULES

IN

# NAVIGATION:

A CONCISE

## PRACTICAL TREATISE ON NAVIGATION:

CONTAINING

SHORT AND IMPROVED METHODS FOR THE DETERMINATION

OF

LATITUDE AND LONGITUDE,

THE

REDUCTION OF THE ELEMENTS IN THE NAUTICAL ALMANAC,

THE TREATMENT AND RATING OF CHRONOMETERS,

ETC. ETC.

BY

WILLIAM N. JEFFERS, JUN.

PASSED MIDSHIPMAN, U. S. NAVY.

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RPJC

# PREFACE.

It was deemed essential to the completeness of this work as a manual of routine, that it should contain rules for determining positions, at sea; the author was therefore requested to write such a work as, in his opinion, was required by the Navigator, limiting it however to a certain size.

I have therefore made such a collection of short rules, and also of certain rigid methods, as appeared to me necessary for the determination of the position at sea, in all the cases which occur in practice.

In doing this, I have not scrupled to extract from the works of various writers within my reach, such methods, observations, and remarks as tended to elucidate the subject: to that valuable work, Raper's Practice of Navigation, I have been particularly indebted. I must also acknowledge my obligations to Professor Wm. Chauvenet, of the U. S. Naval School; from whom, either while under his instruction preparatory to my examination, or during our subsequent intercourse, the greater part of my own knowledge has been obtained. To him I am indebted for the method of equal altitudes, and the methods of correcting the lunar distance, and altitude, for the spheroidal figure of the earth, besides numerous suggestions embodied in the work.

The tables of a work on Navigation, necessarily occupy a most important position; and, as it is essential that the Navigator should be able to rely on their accuracy, I will mention the precautions which have been taken to ensure a degree of accuracy to which it is believed no other work on the subject could, on its first publication, lay claim.

For convenience, Tables XXVII. and XXVIII. were set up by a copy of the second edition of Raper, in which such alterations had been made as were required. They were then read four times before stereotyping, and three times from the plates; finally, sent to the author, by whom they

were read with Hutton and Callet, and, when errors were discovered, compared with Bagay. In these last readings but four errors were discovered which were not in the original tables, in which I have detected numerous and important errors.

The other, and less important tables, have received an equal degree of attention; having been compared with standard tables, or examined by differences throughout.

Table XXI., as well as the *idea* of all the methods in which it is used, was extracted from Raper. The applications of that table to the computation of the Hour-angle, Altitude, and Clearing the Lunar Distance, as given by him, were of comparatively little practical utility, as any one may readily be convinced by turning to that work; the difficulty of interpolation, and their want of accuracy, destroying all confidence in the methods. As modified by the author, they offer not only short, but sufficiently accurate methods of making those calculations: the degree of accuracy is given under each head.

The method of Reducing the Elements in the Nautical Almanac is that practised at the Naval School, and experience has shown that it is more readily understood than the application of the proportional tables usually given to facilitate these reductions. The use of the signs, + and −, is decidedly elementary; the experience of this institution having shown, that those persons who have the greatest difficulty in taking out the corrections, seldom fail to apply them aright, as indicated by the sign.

The various methods for finding the latitude are concise, clear, and of general application. Method V. is of great value, from its application to most cases of night observations, as well as to two observations of the same body, one being near the meridian. Method VI. has not before appeared in any work on Navigation; it is similar to Bowditch's first method, but is believed to be more convenient.

The methods for finding the time are, in addition to the usual method, the application of the Short Method of computing the hour-angle, and the method of equal altitudes, at sea, and on shore. The method of equal altitudes at sea is valuable, particularly in low latitudes; it involves but a slight calculation, and does not require the latitude to any great degree of accuracy.

The methods of rating and keeping account of the chronometer, it is hoped, are fully and clearly explained.

The Short Method of clearing the lunar distance, is believed by the author to be the shortest possible, consistent with accuracy; for dis-

tances exceeding 50°, it will seldom differ more than 3″ from the Rigid Method.

The Rigid Method will give the true distance, from the data, within a single second; it offers the shortest method when accuracy is desired, and has the additional merit of being entirely free from cases.

The method of determining the longitude by the altitude of the moon, has been much improved by the application of the correction for the spheroidal figure of the earth; a correction which was first accurately determined by Prof. Chauvenet, and furnished for this work. Without this correction the method is of little value.

Finally, it is scarcely necessary to say, that it does not come within the limits of this work to teach fully the subject of Navigation, but merely to furnish those who already have an idea of the subject, certain short and accurate methods, not contained in any work in the hands of the American Navigator.

W. N. JEFFERS, Jr.

Naval School, Annapolis,
*March*, 1849.

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# SHORT RULES

IN

# NAVIGATION.

29

## EXPLANATION OF SIGNS AND ABBREVIATIONS USED.

For the sake of brevity, the following signs have been adopted throughout the work.

$+$ is the sign of *addition*, and indicates that the quantity which follows the sign is to be added to those which go before it. When several quantities are placed in the same vertical column, those marked $+$ are to be added together. The sign $+$ is called the *positive* sign.

$-$ is the sign of *subtraction*, and denotes that the number following it must be subtracted from those which precede it. When of several quantities in the same vertical column some are preceded by the sign $+$, and others by the sign $-$, the *difference* of the sum of the positive, and sum of the negative quantities, is the *sum* of all the quantities considered. The sign $-$ is called the *negative* sign.

If a number of logarithms are added together, some marked $-$, and others $+$, if there is an *even* number of logs. marked $-$, the *sum* is to be marked $+$; if an *odd* number marked $-$, the *sum* is to be marked $-$.

In the Reduction of the Elements, &c., the quantity as taken from the Nautical Almanac is indicated by the initial letter enclosed within a parenthesis, thus: (D.) indicates the Declination at noon as taken from the Nautical Almanac. (E.) Equation of Time (R. A.) Right Ascension. (H. P.) Horizontal Parallax, etc. When reduced to the Greenwich date, the parenthesis is omitted.

The logarithmic sines, tangents, &c. being alone used, the word log. before them has been omitted.

$\odot$ signifies the sun. $\mathfrak{D}$, the moon. $*$, a star. $\underline{\odot}$, sun's lower limb. $\overline{\odot}$, upper limb. $\underline{\mathfrak{D}}$, moon's lower limb. $\overline{\mathfrak{D}}$, upper limb. $\mathfrak{D}\,\odot$, sun and moon's nearest limbs. $\odot\,\mathfrak{D}$, farthest limbs.

# CHAPTER I.

## THE INSTRUMENTS USED IN TAKING OBSERVATIONS.

---

### I. The Sextant.

It does not enter into the plan of this work to give detailed directions for performing operations other than those absolutely requisite, and for methods in daily use. The explanations, under this head, will be confined to the adjustment of the line of collimation of the telescope, and finding the index error. These adjustments should be verified each time the instrument is used. The other adjustments are made by the maker, and are not liable to alteration.

#### (1.) *To find the Index Error.*

By the sun—Measure the sun's horizontal diameter, moving the index *forward* on the arc in the order of the divisions, until the limbs coincide—the angle read off will be *on* the arc. Move the index back, which will change the places of the real and reflected images; perfect the contact and read off the angle, which will be *off* the arc. Half the difference of these two readings will be the error, *subtractive* from all altitudes or distances observed, if the reading *on* the arc is the *greater; additive*, if *least.*

The most perfect method of obtaining the index error is to measure the sun's diameter as reflected from an artificial horizon.

If both readings are on the arc, the error is the mean of the two, subtractive; if both off, additive. In this case the error would be nearly half a degree, and the sextant should be adjusted; but in ordinary cases it is preferable to find the error and allow it.

One fourth the sum of the two readings should equal the sun's semi-diameter by the Nautical Almanac.

#### (2.) *Adjusting the Line of Collimation.*

To adjust the line of collimation, or optical axis of the telescope, parallel to the plane of instrument;—Screw in the telescope, and turn the eye-piece until two of the wires are parallel to the plane of the instrument. Select two objects from 100° to 120° distant, as two stars, or the sun and moon, and make an exact contact at the wire nearest the plane of the instrument; slightly alter the plane, and bring the

images in contact upon the other wire. If the contact remains perfect, the adjustment is correct; if they have separated, the object end of the telescope droops; if they overlap, it rises. The adjustment is made by means of the screws in the collar. When this adjustment is defective, the observed angle is always too *great*. The adjustments of an instrument having once been made, the screws are never to be touched except from necessity, and then with the greatest possible caution.

---

## II. The Artificial Horizon.

Altitudes less than 60° may be observed with great accuracy on shore on an artificial horizon. This is a shallow trough filled with quicksilver, protected from the disturbing effect of the wind by a glass screen or roof. To avoid the errors of want of parallelism in its surfaces, the screen should be used only when necessary. A cup filled with oil, tar, molasses, or spirits may be substituted; but quicksilver, as possessing the greatest reflecting power and quickly regaining its level after any disturbance, is to be preferred. By the use of this instrument double the altitude of the body observed is obtained; consequently, in halving the angle shown by the sextant we halve all errors of observation.

To prevent the formation of a film or scum on the surface of the quicksilver, place the finger over the orifice of the bottle and give it a shake in an inverted position; ease the finger and allow the mercury to flow into the trough, keeping the bottle inverted, and taking care to stop the opening before the last portion with the dross flows out. If a steady foundation can be obtained, it will be more convenient to place the horizon in an elevated position; if it is placed on the ground, the observer should seat himself so that his knees may steady both elbows. Bring the sun down to the image in the horizon without the telescope, then screw it in and obtain the focus; lastly, bring the two images to nearly equal brightness by the adjusting screw of the telescope.

In taking observations for equal altitudes, or time sights, altitudes should be taken to every 5′ or 10′ of arc, as they are most easily valued by the equality or discrepancy of the times.

---

## III. The Comparing, or Deck Watch.

To avoid moving the chronometer it becomes necessary to employ a watch to note the time when observations are made, whether on deck or ashore. Any watch with a second-hand will answer the purpose, but as the watch and chronometer will not in general go exactly together, they should be compared both before and after the observation, in order to find the watch rate in the interval.

This comparison is best effected by one person, and in the following manner. Chronometers usually beat half-seconds, watches 5 beats in 2ˢ. When the second-hand of the chronometer is at (say) 35ˢ, commence to count the beats; at 40ˢ note

the second and tenth of a second shown by the watch; mark also at 50ˢ, and 60ˢ, and take the mean of the three comparisons. When great accuracy is required, the comparison should be made at every 10ˢ for 1ᵐ. If the difference between the watch and chronometer be the same before and after the observation, the time of observation by chronometer is readily found by adding to it the difference between the time of comparison and time of observation by watch.

Should there be a rate, a correction must be applied. For example:—

1st Comparison.

| *Watch.* | | | | *Chron.* | | |
|---|---|---|---|---|---|---|
| h | m | s | | h | m | s |
| 9 | 4 | 47.5 | | 2 | 8 | 40 |
| | | 57.3 | | | | 50 |
| | 5 | 7.4 | | | 9 | 0 |
| 9 | 4 | 57.4 | mean | mean 2 | 8 | 50 |

Time of obs. 9 40 27

2d Comparison

| | | | | | | |
|---|---|---|---|---|---|---|
| h | m | s | | h | m | s |
| 9 | 54 | 49.9 | | 2 | 58 | 40 |
| | | 59.7 | | | | 50 |
| | 55 | 9.6 | | | 59 | 0 |
| 9 | 54 | 59.73 | mean | mean 2 | 58 | 50 |
| 9 | 4 | 57.4 | 1st comp | 2 | 8 | 50 |
| | Gain | 2.33 | watch rate. | Interval | | 50 |

The watch has gained on the chron. 2ˢ.33 in 50ᵐ. The observation was taken at an interval from 1st Comp. of 35ᵐ 30ˢ. For the prop. gain then we have

$$50^m : 35^m.5 = 2^s.33 : 1^s.8.$$

This subtracted from the interval to the obs. gives 2ʰ 44ᵐ 18ˢ.2, the time by chron. at obs. When the watch rate is very large, and several observations are taken separated by considerable intervals, each time should be corrected for its own proportional rate.

---

## IV. The Chronometer.

The following directions relative to the treatment of chronometers have been collected from various sources, and are believed to embody all the information required for their use at sea.

The chronometer is a superior kind of watch, and its advantages for measuring time more accurately, are derived from the superior manner in which it is made, reduced friction from its peculiar construction, and being supplied with a compensation balance, which when properly adjusted counteracts the effects of changes of temperature. The reputation of the maker is the only guarantee which the purchaser can have for the satisfactory performance of the instrument.

The best position on shipboard for the chronometer is as near the centre of motion and as much removed from liability to shocks and change of temperature as possible. It should be placed in a chest resting upon and being surrounded by curled hair, or other elastic material, the chest being firmly secured.

Magnetism affects the rates of chronometers; it is therefore necessary that nothing magnetic be placed near them,* and that they should remain in whatever position they are at first placed: the local attraction of the materials of which the vessel is composed affects the balance.

The principal cause of alteration in the rates of chronometers is change of temperature; to obviate this change, some surveying vessels keep the temperature of the chronometer-room invariable by means of lamps. The rates do not always change immediately, but in general some time after the change of climate.

If there is but one chronometer on board, it should never be taken from ship to shore, or on deck, for the purpose of marking time. The shocks which it may receive, and the change of temperature, generally alter its rate. A watch with a second-hand may be used to mark the time, being compared with the chronometer before and after the observation, as directed in the preceding article. If there are more than one, the one moved should be compared, before and after moving, with another chronometer, to ascertain whether its rate has been disturbed. In fact, the rate should always be ascertained, if possible, when the chronometer is on board ship; for it has been found by experience that the motion of a chronometer is generally accelerated after being received on board, whereby a gaining rate will be increased, and a losing one diminished. This effect has been ascribed to the magnetic action exerted by the iron in the vessel on the inner rim of the balance, which is made of steel. When the rate has been accelerated, the longitude resulting from observations made with it will be to the westward of the true longitude; when retarded, too far to the eastward. The stay should always be carefully set before moving a chronometer, as they are often injured from neglect of this precaution.

It should be wound at regular intervals, to ensure its being wound and that the same parts may undergo the same constant action. The rate generally changes after a chronometer has been permitted to run down. After winding, always look at the face, to see that it has not stopped; and at the index, to be certain that it is wound *up*: it is not uncommon for careless or inexperienced persons to turn the ratchet-key the wrong way, leaving the chronometer unwound.

When a chronometer is wound, after running down, it is set a-going by giving it a quick horizontal circular motion, first taking the precaution to set the stay.

Chronometers are liable to jump one or two seconds in the daily rate without any apparent cause, and then reassume their former rate in a few days; but as the same cause seldom affects several chronometers in the same way and to the same extent, the mean of several is entitled to more confidence than any single result.

---

* I have heard of a case where the master of a vessel kept his spare compass and chronometer in the same locker!

# CHAPTER II.

## TAKING OBSERVATIONS.

---

### I. Observing Altitudes.

#### (1.) *At Sea.*

When observing altitudes, a telescope or plain tube should always be used, to ensure the eye and contact of the images being in the same plane, as the altitude must be measured to the point of the horizon vertically beneath the body. When the altitude is greater than 60°, both the altitude and its supplement, or distance from the opposite point of the horizon, may be measured by a sextant. Half the diff. of the two readings will be the app. zenith dist. By this means errors of dip and index error are removed. The dip being at all times uncertain, whenever precision is required, (as in observing altitudes of the moon for absolute longitude,) it is advisable to attend to this consideration.

When the air and sea are of the same temperature, the horizon retains its true or mean place: if the air is cooler than the sea, the horizon will appear below its mean place; when warmer, above. This difference of temperature between the air and sea increases from the equator to the poles, hence the variation of the dip will increase accordingly. Capt. Owen found a change in the tropics of about 4′; in the arctic regions it has been found to vary 18′.

When both the altitude and its supplement are measured by one observer, the time must be noted at each of the two contacts; half the difference of the altitude and its supplement is the app. zen. distance, corresponding to the mean of the times.

When fog obscures the sea horizon from the deck, a new horizon may often be obtained by descending the ship's side, or from a boat.

In hazy weather altitudes of the centre of the sun or moon may often be obtained when the limbs are not visible; the mean of several such altitudes, it is asserted, has frequently given reliable results.

Altitudes of the moon taken at night are frequently very uncertain, the dark shadows on the water rendering it difficult or impossible to discern the horizon. In such cases the supplement should be observed, the *supplement* of which corrected for index error and dip is the app. alt.

Altitudes of the stars are best observed at twilight, when, if the sky is clear, the horizon is strongly defined. The chief objection to night observations is the difficulty of reading off, which is in general exceedingly troublesome.*

---

* Sextants made by Gambey and other French makers are not liable to this objection in so great a degree, the reflector being placed in a more convenient position.

When a telescope is used, the unemployed eye must be closed; but when a plain tube is used, it should be kept open; because the image being seen by both eyes under the same magnitude, one assists the other. This should always be practised in observing stars at night.

In addition to instrumental errors, altitudes taken on the sea horizon are subject to errors which change with circumstances.

1st. The undulations of the waves cause the horizon to be in continual motion. 2d. The rise and fall of the observer, both from the lifting of the vessel by the waves, and by her rolling, cause the dip to be continually changing. For these reasons the usual practice of rejecting discrepant altitudes is founded on error, and a fair mean of all the altitudes should be taken: should the observer doubt their accuracy, let a sufficient number be taken to eliminate the errors of observation.

The height of the eye should be ascertained with some precision, particularly when the observer is near the surface of the water, as the dip then changes most rapidly. If altitudes be observed from the top, the horizon will appear better defined, and the variations of the dip by the motion of the ship will be less sensible; also, the difference of temperature of the sea and air appears to affect the place of the visible horizon less as the observer is more elevated. When precision is required, altitudes should be taken from aloft.

### (2.) *On Shore.*

On shore, where the dip is dispensed with, altitudes may be obtained with great accuracy on an artificial horizon.

When the body observed is *rising*, and the lower limb is brought in contact with the image in the quicksilver, the images are continually *separating;* but when the *upper* limb is observed they are continually *overlapping;* and the contrary when the sun is falling. It is necessary to attend to this, as it is sometimes doubtful, especially with the inverting telescope, which limb was observed.

If circumstances will permit, the alt. should first be obtained roughly and the index set to the next degree, the instant of contact noted and the index again set to the next division on the arc. This method is preferable to moving the tangent-screw during the observation, which disturbs the attention of the observer; it is also more convenient to set the index than to read off an unknown angle.

The roof of the artificial horizon, when used, should be reversed at each set of three or five altitudes, in order to remove the effects of errors in the shades. One face should be marked A, the other B, and these letters noted against the alts.

To avoid the errors of the colored shades of the sextant, the colored eye-pieces to the telescope should be used instead, when observing bright objects.

The accuracy with which a set of altitudes has been taken, may be inferred from the agreement of the intervals of time between the equal changes of alt. There will, in general, be a compensation of errors; and one interval being too small, another too great, a sufficient number of observations will eliminate the errors. If, however, the observations be continued through too long a portion of time, an error of a new kind will be introduced by the unequal variation of altitude, which does not vary at the same rate at the beginning, middle, and end of the series.

## II. Observations with and without Assistants.

The positions of the heavenly bodies with respect to the observer being in a continual state of change, their altitudes or distances correspond to a particular instant of time. If, therefore, more than one body is to be observed at the same time, either several observers are required, or one person must obtain the several angles and afterwards reduce them to the same instant by calculation.

The impropriety of the custom of employing assistants, when two or more altitudes or distances are to be observed at sea, will appear manifest, on considering the nature of the errors of alt.; for it is evidently impossible for an observer to keep the motion of the index so exactly adjusted to the variations of altitude, during the irregular and violent motions of the ship, as to be able to seize the alt. at the word of command.

An assistant is, however, useful for noting the times. Being provided with a watch with a second-hand, he places himself near the observer. The observer, a few seconds before the contact of the objects is complete, cries "Look out!" When the contact is perfect, he cries "Mark!" or "Stop!" when the assistant writes down the second, minute, and hour. The observer then reads off the angle, which the assistant writes down. Three, five, or more altitudes make a set of sights. The times and altitudes are each added together and divided by the number of observations, giving the mean time and alt.

When two sets of observations are taken by the same or different persons, and the means of the times are not identical, they may be reduced to the same instant by calculation. The observations can thus be taken by one observer, independent of the errors of inexperienced assistants. When the observer notes his own time he holds his watch in his hand, or places it where he can hear it tick plainly. In the latter case the first beat after the instant of contact he counts 1, the next 2, &c.; then, looking at the watch, he continues to count until the second-hand arrives at a marked number of seconds, as 10, 15, &c. He then writes down the seconds and after them the number of beats to be subtracted, reads off the alt., sets it down and proceeds as before. The sum of the beats is to be subtracted from the sum of the times before the mean is taken.

---

## III. Observing Lunar Distances.

The angular distance of the moon from any celestial body being constantly changing, each of the distances corresponds to a certain instant of time. The distance of the moon from the sun, planets, and certain stars, at the end of every three hours, has been given in the Nautical Almanac, thus affording the time of observation at Greenwich, and thence the longitude of the observer.

The alts. of the moon, and of the other body observed, are required at the instant at which the distance is measured. Great precision is not, however, required in the alts.

The observer, to be habitually independent of assistance in the observations, as well as to avoid the errors mentioned in the preceding article, should observe both altitudes and the distance himself. First observe the alt. of the body farthest from the meridian, then that of the other body, and then the distance; concluding with the alts. in the reverse order. The *outer* body preserving uniformity in its alt. for a longer time than the other, it may be reduced to an intermediate time with least error. The time is, of course, to be noted at each contact.

A telescope should always be used in observing lunar distances. The power employed should, however, only be such as to compensate by a larger image for increased unsteadiness, without rendering it too difficult to keep the object in the field.

*To observe the Distance.*—Set the index to the estimated distance. If the sun is one of the bodies, put down one or more shades to screen the central mirror; direct the sight to the moon, and, holding the sextant in the plane of the two bodies, slowly vibrate it until the two bodies are seen. Make the contact roughly, clamp the index, screw in the telescope, (previously adjusted to distinct vision by the moon,) and complete the contact. Observe, at least, three or five distances, and take a fair mean of the whole.

If one of the bodies is a star or planet, direct the telescope to the star, make the contact nearly between the star and the illuminated edge of the moon, screw in the telescope, and complete the contact by bisecting or splitting the star on the moon's limb. When the moon is bright it is necessary to use a shade.

The relative brightness of the object and image is most conveniently adjusted by altering the distance of the telescope from the plane of the sextant, by means of the screw for this purpose, as this causes a greater or less quantity of light to proceed to the eye from the silvered or brightest part of the horizon-glass.

The setting of the index, before mentioned, is a more important step in observing with a star than with the sun; for the amount of distance is often the only security for employing the right star.

When convenient, distances should be observed of stars on opposite sides of the moon, in order to remove the unknown errors of the instrument.*

At sea, when the ship has much motion, the observer fixes himself firmly in a corner, or lies on his back on the deck, in order to remove as much as possible the sense of bodily effort and inconvenience, which disturbs the eye and the attention.

The limits of distance should fall within the greatest and least distances in the N. A. The alts. should not be less than 5° or 6°, and when the barometer and thermometer are not at hand, not less than 12° or 15°, especially in very hot or very cold weather.

The temperature and density of the air are of great importance in the lunar observation; particularly when the alts. of the moon and sun, or star, differ considerably. The bar. and therm. should therefore be noted, and the mean refraction corrected by Table VI.

---

* Most authors erroneously assert that this will remove constant errors of observation

# CHAPTER III.

## PRELIMINARY OPERATIONS.

---

Under this head the subordinate computations have been collected, which are common to more than one of the methods given for ascertaining the position of the observer.

### I. Reduction of Time to Decimals.

The principal difficulty met with by inexperienced navigators, is in taking out quantities from the Nautical Almanac, and reducing them to the Greenwich time of observation. This difficulty may perhaps be removed by a brief explanation of a method of reduction, simpler and more accurate in practice than the use of the small tables usually given to facilitate this operation.

Many computers take the daily or hourly differences from the N. A., and proportion for the hours, minutes, and seconds of the given time; but by reducing the time to the decimal of a day, or to hours and the decimal of an hour, the work may be facilitated. Thus—Divide the seconds and minutes by 60, to reduce them to the decimal of the next higher denomination; divide the hours and decimal of an hour by 24, to reduce them to the decimal of a day. It is unnecessary to set down the divisor, as the operation may readily be performed mentally.

*Example.* Reduce $4^h\ 16^m\ 32^s$ to the decimal of a day.

| | |
|---|---|
| $4^h\ 16^m.53$ | hours, minutes, and dec. of a minute. |
| $4^h.275$ | hours, and dec. of an hour. |
| $0^d.178$ | decimal of a day. |

---

### II. Decimal Multiplication.

Having thus reduced the time to hours and decimals, or the decimal of a day, the following method of multiplying a mixed number or decimals, more simple than that usually taught, will save the unnecessary labor of obtaining figures which do not increase the accuracy of the result.

Write the multiplier under the multiplicand as in whole numbers, and place a new decimal point after the first figure of the multiplier; remove the decimal point

in the multiplicand as many places in the contrary direction,* and reject the figures in excess, should there be any. Commence the multiplication with the figure in the unit's place, and cut off one figure from the right of the multiplicand after each multiplication. Set the partial products under each other from the right, increasing the first figure by what would arise from the product of the rejected figure by the multiplier. The decimal point in the product will fall under the new decimal point in the multiplicand.

The following examples are multiplied by the old and new methods, showing that the latter is as accurate as the former, and requires but half the figures.

*Ex.* 1. Multiply 38.732 by 12.34

| | |
|---|---|
| 38.7,3\|2 | 38.732 |
| 1,2.34 | 12.34 |
| .3873 | 144928 |
| 775 | 116196 |
| 116 | 77464 |
| 15 | 38732 |
| 477.9 | 477.85288 |

*Ex.* 2. Multiply 57.05 by .47

| | |
|---|---|
| 5,7.\|05 | 57.05 |
| 4,7 | .47 |
| 228 | 39935 |
| 40 | 22820 |
| 26.8 | 26.8135 |

In the first example the decimal point was removed one place to the left in the multiplier, which was equivalent to dividing by 10; that the value of the product might not be affected, the multiplicand was increased 10 times its former value by removing the dec. point one place to the right. In the second example the reverse operation was performed. With a very little practice it will be unnecessary to remove the dec. point; the operation can be performed mentally.

---

## III. Decimal Division.

The abridged method of division also simplifies many calculations in so great a degree that it is here introduced.

This method is founded on the principle, that, in the ordinary mode of division, each of the figures of the quotient depends, in general, only on the first two or three figures of the dividend, and the first or first two figures of the divisor. Whence it follows that we may obtain the true quotient, without employing the last figures of each partial dividend. Thus—Place the divisor to the right of the dividend, and place a new decimal point after the first figure of the divisor; remove the decimal point in the dividend as many places in the *same* direction, (prefixing ciphers, if necessary,) and reject the figures in excess in either.

If the divisor should be greater than the dividend, there will be no integral figures in the quotient;—cut off one figure from the right of the divisor, and proceed to find the first figure of the quotient, carrying the units arising from the product of the figure cut off by the quotient figure;—cut off one figure as before, and divide the new dividend for the second figure of the quotient. Continue this process until an exact quotient, or as many decimal places are obtained as there are decimal

* This is evidently equivalent to multiplying the one and dividing the other by the same number; —their product will be the same.

places in the divisor; a greater number would not increase the accuracy of the result.

If the dividend is greater than the divisor, the integral figures in the quotient will be those arising from the division of the integral figures of the dividend by those of the divisor: they are readily determined by inspection.

When but a limited number of decimals is required in the quotient, reject, in both dividend and divisor, the figures in excess of the required number.

*Ex.* 1. Divide 477.853 by 12.34

| | |
|---|---|
| 47,7.8\|53 | 1,2.3\|4 |
| 3702 | 38.73 |
| 1077 | |
| 987 | |
| 90 | |
| 86 | |
| 4 | |
| 4 | |

*Ex.* 2. Divide 57.76 by 191.6

| | |
|---|---|
| ,57.76 | 1,91.6 |
| 5748 | .3014 |
| 28 | |
| 19 | |
| 9 | |
| 8 | |

## IV. The Greenwich Date.

Much needless confusion has been produced, by the introduction, into treatises on Navigation, of three distinct modes of reckoning time: Sea, Civil, and Astronomical account. The Civil day begins at midnight and ends the following midnight; the first $12^h$ are marked A. M., the last $12^h$ P. M. The astronomical day begins at noon, 12 hours after the civil day; the hours are numbered from 1 to 24 in numeral succession. The use of sea-account being productive of much inconvenience, has been abandoned in the U. S. Navy, and civil time only will be used in the following pages.

All the calculations of the Nautical Almanac are adapted to astronomical time at Greenwich; it consequently becomes necessary to know the *Greenwich date*,* or *astronomical day and hour at Greenwich*, when the observation was taken. Bowditch, by general use of sea-account, and occasional introduction of a chronometer showing Greenwich Ast. time,† or a watch regulated to apparent time, with a view of rendering his methods more immediately practical, has rendered them in reality less practical. The student is necessarily led into a habit of performing operations without comprehending the principles which justify the rules, when the *principle* is often clearer than the *rule*.

The civil day commencing at midnight $12^h$ before the Ast. day, if the local civil time is A. M. it will evidently fall in the preceding Ast. day. The local Ast. date will be, hour A. M. $+12^h$.

If the local civil time is P. M., the local Ast. date will be the same as the civil day hour P. M.

* The term Greenwich date is adopted as expressing both day and hour.

† A chronometer shows Greenwich mean civil time.

*Ex.* 1. Required local Ast. date June 1st, 9 A.M.

Civil time June 1st, $9^h\ 0^m$ A.M.
$+\ 12$
Ast. date May 31st, $21\ 0$

*Ex.* 2. Required local Ast. date June 1st, 3 P.M.

This is evidently June 1st, $3^h$ Ast. date.

The Greenwich date is always given in *mean time*, unless the contrary is expressed.

*To find the Greenwich date, without the chronometer.*

(1.) In W. lon. Find the Ast. date, and add to it the lon. in time; if the sum exceeds $24^h$, deduct $24^h$ and reckon the time *next* day.

*Ex.* 1. Required Greenwich date June 1st, 9 A.M. civil time, lon. $5^h\ 6^m$ W.

Civil time June 1st, $9^h\ 0^m$ A.M.
$+\ 12$
Ast. date May 31st, $21\ 0$
W. lon. $+\ 5\ 6$
Greenwich date June 1st, $2\ 6$

*Ex.* 2. Required Greenwich date June 1st, 3 P.M. civil time, lon. $5^h\ 4^m$ W.

Ast. date June 1st, $3^h\ 0^m$
$+\ 5\ 4$
Greenwich date June 1st, $8\ 4$

(2.) In E. lon. From the Ast. date subtract the lon. in time. If the lon. in time be greater than the Ast. date, add $24^h$ to the latter and reckon the time the *preceding* day.

*Ex.* 1. Required Greenwich date May 15th, 7 A.M., lon. $4^h\ 30^m$ E.

Ast. date 14th, $19^h\ 0^m$
E. lon. $-\ 4\ 30$
Greenwich date 14th, $14\ 30$

*Ex.* 2. Required Greenwich date Oct. 1st, $3^h\ 45^m$ P.M., lon. $7^h\ 20^m$ E.

Ast. date 1st, $3^h\ 45^m$
$-\ 7\ 20$
Greenwich date Sept. 30th, $20\ 25$

(3.) When it is noon at the place. In W. lon. the Greenwich date is the lon. in time. In E. lon., subtract the lon. in time from $24^h$; the remainder is the Greenwich date the *preceding* day.

*To find the Greenwich date by the chronometer.*—As only $12^h$ are given on the face of a chronometer, it shows only the time after noon or after midnight; therefore the local time and approximate lon. are required, to know whether it is A.M. or P.M. at Greenwich.

Find the Greenwich date roughly by the method above given; this will show whether the chronometer shows A.M. or P.M. Apply the error brought up to the time, and, if necessary, add $12^h$ to the reading of the face of the chronometer.

*Ex.* Oct. 10th, lon. $7^h\ 40^m$ E., about 3 P.M.: Face of chron. $7^h\ 14^m\ 30^s$, error slow $2^m\ 19^s$. Required Greenwich date.

| | | |
|---|---|---|
| Ast. date - - - | 10th | $3^h\ 0^m$ |
| E. lon. - - - - | | $-\ 7\ 40$ |
| Approx. Greenwich date | 9th | $19\ 20$ |
| * Greenwich date by chron. | 9th | $19^h\ 16^m\ 49^s$ |

* A little practice will render the deduction of the Greenwich date very easy, without going through all the preceding steps.

## V. Reduction of the Elements in the Nautical Almanac to any Meridian.

### (1.) *The Sun's Declination.*

Find the Greenwich date. Take from the N. A. page II.,* the dec. for noon, and the hourly diff. If the dec. is increasing, mark the diff. +; if decreasing, —. Reduce the time to hours and decimals of an hour, and multiply the hourly diff. by it; reduce the product to minutes and seconds, and add it to, or subtract it from, the dec. at noon as indicated by the sign.

*Ex.* 1. Greenwich date, Nov. 1st, 1848, $10^h\ 15^m$. Required ⊙'s Dec.

| | | |
|---|---|---|
| ⊙'s (D.) | 14° 34′ 44.″7 S. | h. diff. +47.″61 |
| | +8 8 | 10.25 |
| ⊙'s D. | 14 42 52.7 S. | 4761 |
| | | 95 |
| | | 24 |
| | | 488.0 |

*Ex.* 2. Greenwich date, June 30th, 1848, $7^h\ 16^m$. Required ⊙'s Dec.

| | | |
|---|---|---|
| ⊙'s (D.) | 23° 10′ 5.″8 N. | h. diff. −9.″91 |
| | −1 12 | 7.27 |
| ⊙'s D. | 23 8 53.8 N. | 6937 |
| | | 198 |
| | | 69 |
| | | 72.04 |

### (2.) *The Sun's Right Ascension.*

Find the Greenwich date. Take from the N. A. the R. A. for noon, and the h. diff. Reduce the time, and multiply the h. diff. by it; add the product (reduced to minutes and seconds) to the R. A. at noon. If the sum exceeds $24^h$, reject $24^h$.

*Ex.* 1. Greenwich date, June 4th, 1848, $4^h\ 13^m$. Required ⊙'s R. A.

| | | |
|---|---|---|
| ⊙'s (R. A.) | $4^h\ 50^m\ 12.^s62$ | h. diff. +10.$^s$29 |
| | 43.4 | 4.22 |
| ⊙'s R. A. | 4 50 56.02 | 412 |
| | | 20 |
| | | 2 |
| | | 43.4 |

*Ex.* 2. Greenwich date, March 19th, 1848, $23^h\ 30^m$. Required ⊙'s R. A.

| | | |
|---|---|---|
| ⊙'s (R. A.) | $23^h\ 56^m\ 28.^s03$ | h. diff. +9.$^s$097 |
| | 3 33.7 | 23.5 |
| ⊙'s R. A. | 0 0 01.73 | 1819 |
| | | 273 |
| | | 45 |
| | | 213.7 |

### (3.) *The Equation of Time.*

Find the Greenwich date. Take the equation of time and h. diff. from the N. A.; reduce the time and multiply the h. diff. by it; add the product if the eq. is increasing, subtract if decreasing.

*Ex.* 1. Greenwich date, Nov. 15th, 1848, $5^h\ 6^m\ 7^s$. Required Eq. of time.

| | | |
|---|---|---|
| (E.) | $15^m\ 9.^s81$ | h. diff. −0.$^s$46 |
| | −2.35 | 5.1 |
| E. | 15 7.46 | 230 |
| | | 5 |
| | (Add. to app. time) | 2.35 |

*Ex.* 2. Greenwich date, March 22d, 1848, $5^h\ 56^m$. Required Eq of time.

| | | |
|---|---|---|
| (E.) | $6^m\ 55.^s84$ | h. diff. −0.$^s$77 |
| | −4.54 | 5.9 |
| E. | 6 51.30 | 385 |
| | | 69 |
| | (Add. to app. time) | 4.54 |

* If the Greenwich date is given in app. time, take the dec. from p. I.

### (4.) *The Moon's Semi-Diameter.*

The variation in $12^h$ not exceeding $8''$, the semi-diameter may consequently be taken from the N. A. at sight.

### (5.) *The Moon's Horizontal Parallax.*

The Moon's Hor. Par. may generally be taken from the N. A. at sight.

*Accurately.*—Find the Greenwich date. If the Greenwich time is less than $12^h$, take out the hor. par. for the noon and mid. of the given day; when it exceeds $12^h$, take out the quantities for the mid. of the same day and the noon of the next. Take their diff., which is the variation in $12^h$. Multiply this variation, divided by 12, by the time from noon or mid., and add or subtract the product as the par. is increasing or decreasing. To correct the par. for the spheroidal figure of the earth, *add* the correction Table XXV.

*Ex.* 1. Greenwich date, Nov. 12th, $5^h\ 6^m$. Required ☽'s Hor. Par.

| | | | |
|---|---|---|---|
| ☽'s (H. P.) noon | $61'\ 10.''2$ | diff. $12^h$ | $-24.''5$ |
| | $-11.4$ | | 2.04 |
| ☽'s H. P. | $60\ 58.8$ | | 5.6 |
| | | | 102 |
| | | | 12 |
| | | | 11.4 |

*Ex.* 2. Lat. 50° N. Greenwich date, March 4th, $15^h\ 4^m$. Required ☽'s Hor. Par.

| | | | |
|---|---|---|---|
| ☽'s (H. P.) mid. | $60'\ 9.''3$ | diff. $12^h$ | $+14.''5$ |
| | $+3.7$ | | 1.2 |
| Corr. T. 25. | $+7.$ | | 3.1 |
| ☽'s H. P. | $60\ 20.0$ | | 36 |
| | | | 1 |
| | | | 3.7 |

### (6.) *The Moon's Declination.*

Find the Greenwich date. Take out of the N. A. the dec. corresponding to the hour of the Greenwich time, and also the diff. for $10^m$. Multiply this diff. by the minutes and tenths of the given time, cut off one more decimal than the product contains, and add or subtract the product, as the dec. is increasing or decreasing.

*Ex.* 1. Greenwich date, Mar. 10th, $4^h\ 50^m$. Required ☽'s Dec.

| | | | |
|---|---|---|---|
| ☽'s (D.) at $4^h$ | $15°\ 46'\ 26.''7$ N. | diff. $10^m$ | $+55.''73$ |
| | $+4\ 39$ | | 50. |
| ☽'s D. | $15\ 51\ 5.7$ N. | | 279. |

*Ex.* 2. Greenwich date, Nov. 19th, $18^h\ 10^m$. Required ☽'s Dec.

| | | | |
|---|---|---|---|
| ☽'s (D.) at $18^h$ | $1°\ 59'\ 11''$ N. | diff. $10^m$ | $-96.''55$ |
| | $-1\ 36.6$ | | |
| ☽'s D. | $1\ 57\ 34.4$ N. | | |

### (7.) *The Moon's Right Ascension.*

Find the Greenwich date. Take out the R. A. for the hour, and the diff. of this and the R. A. for the next hour. Multiply this diff. by the minutes and tenths, (reduced to the dec. of an hour,) and add the product. If the sum exceeds $24^h$, reject $24^h$.

*Ex.* 1. Greenwich date, Nov. 18th, $3^h\ 7^m\ 12^s$. Required ☽'s R. A.

| | | | | |
|---|---|---|---|---|
| ☽'s (R. A.) at $3^h$ | $10^h\ 32^m\ 52.^s88$ | h. diff. | $+2^m\ 02.^s6$ |
| | $+14.7$ | | 122.6 |
| ☽'s R. A. | $10\ 33\ 7.58$ | | .12 |
| | | | 123 |
| | | | 24 |
| | | | 14.7 |

*Ex.* 2. Greenwich date, May 27th, $7^h\ 37^m$. Required ☽'s R. A.

| | | | |
|---|---|---|---|
| ☽'s (R. A.) at $7^h$ | $23^h\ 59^m\ 30.^s37$ | h. diff. | $+2^m\ 15.^s34$ |
| | $+1\ 23.9$ | | 135.34 |
| ☽'s R. A. | $0\ 0\ 54.27$ | | .62 |
| | | | 812 |
| | | | 27 |
| | | | 83.9 |

## VI. Miscellaneous Calculations.

### I. Conversion of Times.

(1.) *To convert Apparent Time into Mean Time.*

Find the Greenwich date in App. time, to which reduce the Eq. of time taken from p. I. of the N. A., and apply it as there directed. If the Eq. of T. when subtractive exceeds the App. T., add $24^h$ to the latter and date the time on the preceding day.

(2.) *To convert Mean Time into Apparent Time.*

Find the Greenwich date, to which reduce the Eq. of T. from p. II. of the N. A., and apply it to the given M. T. as there directed. If the Eq. of T. when subtractive exceeds the M. T., add $24^h$ to the M. T. and date the time on the preceding day.

(3.) *To convert an Interval of Mean Time into an Interval of Sidereal Time.*

Enter the table p. 568 of the N. A. with the Mean time, and take out the corresponding Sidereal time. Or, to the log. of the Mean time (in hours and dec. of an hour) add the constant 9.99881: their sum will be the log. of the Sid. T. in hours and decimals.

(4.) *To convert an Interval of Sidereal Time into an Interval of Mean Time.*

Enter the table p. 570 of the N. A. with the Sid. T., and take out the equivalent Mean time. Or, to the log. of the Sid. time (in hours and decimals) add the constant 0.00119: their sum will be the log. of the Mean time in hours and decimals.

(5.) *To convert Sidereal Time into Mean Time.*

Or, having given the Right Ascension of the Meridian, to find Mean Time.

Take from the N. A. the Sid. time at Mean noon. To the constant 0.9937 add the log. of the lon. in time: their sum will be the log. of a correction in seconds, to be added to the Sid. time at Mean noon in W. lon., to be subtracted in E. lon. From the given Sid. T. (increased by $24^h$ if necessary) subtract this reduced Sid. T. at noon; the remainder is a Sidereal interval to be converted into Mean time by (4.)

(6.) *To convert Mean Time into Sidereal Time.*

Or, having given the Mean time, to find the R. A. of the Meridian.

Take from the N. A. the Sid. time at Mean noon. To the constant 0.9937 add the log. of the lon. in time: their sum will be the log. of a correction in seconds,

to be *added* to the Sid. time at Mean noon in W. lon., to be *subtracted* in E. lon. Convert the given Mean time into Sid. T. by (3.), and add to it the reduced Sid. T. at noon; their sum (rejecting $24^h$ if it exceed $24^h$) is the Sid. T. required.

## II. To find the Hour-angle of a Body, Mean Time being given.

### (1.) *Hour-angle of the Sun.*

Find the Greenwich date. Reduce to it the Eq. of T., and apply it to the M. T. as directed p. II. of the N. A. If the given time is A. M. subtract it from $12^h$ to obtain the mer. dist., or hour-angle, E. of the meridian. If the time is P. M. it is the hour-angle W. of the mer.

*Ex.* 1. July 9th, 1848, lon. 16° E. at $17^h\ 20^m\ 51^s$ Mean time. Required Sun's hour-angle.

The Greenwich date is 9th $16^h\ 17^m$.

| | | m | s | | s |
|---|---|---|---|---|---|
| (E.) | | 4 | 53.07 | h. diff. | +0.357 |
| | | | +5.82 | | 16.3 |
| E. | | 4 | 58.89 | | 357 |
| | 17 | 20 | 51 | | 214 |
| Hour-angle | 17 | 25 | 49.89 W. | | 11 |
| or | 6 | 34 | 10.11 E. | | 5.82 |

*Ex.* 2. Aug. 4th, 1848, lon. 47° 21′ W. at $3^h\ 18^m\ 20^s$ M. T. Required Sun's hour-angle.

The Greenwich date is 4th, $6^h\ 28^m$.

| | | m | s | | s |
|---|---|---|---|---|---|
| (E.) | | 5 | 46.87 | h. diff. | −0.24 |
| | | | −1.56 | | 6.5 |
| E. | | 5 | 45.31 | | 144 |
| | 3 | 18 | 20 | | 12 |
| Hour-angle | 3 | 12 | 34.69 W. | | 1.56 |

### (2.) *Hour-angle of a Star.*

Find the Greenwich date; to which reduce the Sid. T. at Mean noon. To the M. T. add the reduced Sid. T., and from the sum (increased, if necessary, by $24^h$) subtract the star's R. A.; the result is the hour-angle W. If the hour-angle exceeds $12^h$ subtract it from $24^h$; the remainder is the hour-angle E.

### (3.) *Hour-angle of a Planet or the Moon.*

Find the Greenwich date; to which reduce the Sid. T. at Mean noon, and the R. A. of the body, and proceed as with a star.

## III. To find the Hour-angle, the Altitude being given.

### *Short Method.*

With the lat. and dec. enter Table XXI. and take out M and N. (See Explan. of Tables.) With the alt. enter Table XXII. and take out the factor, by which multiply M and call the product P.

When the lat. and dec. are of *contrary* names, take the *sum* of P and N: the time corresponding to this sum in Table XXII. subtracted from $6^h$, will be the hour-angle required.

When the lat. and dec. are of the *same* name, take the *diff.* of P and N: when P *exceeds* N, the time corresponding *subtracted* from $6^h$ is the hour-angle; but when P is *less* than N, the time corresponding added to $6^h$ is the hour-angle.

*Ex.* 1. Lat. 24° 16′ N., Dec. 10° 36′ S., Alt. 28° 10′. Required the hour-angle.

| | | |
|---|---|---|
| 24° 16′ and 10° 36′ | M 111.5 | N 8.5 |
| Alt. 28° 10′ Factor | 47.20 | P 52.6 |
| | 4460 | (sum) 61.1 |
| | 781 | |
| | 22 | |
| | P 52.63 | |

Hour-angle $3^h\ 29^m\ 20^s$ (agreeing with computation by logs.)

*Ex.* 2. Lat. 51° 30′ N., Dec. 6° 35′ S., Alt. 13° 40′. Required the hour-angle.

| | | |
|---|---|---|
| 51° 30′ and 6° 35′ | M 161.7 | N 14.5 |
| Alt. 13° 40′ Factor | 23.63 | P 38.2 |
| | 3234 | (sum) 52.7 |
| | 485 | |
| | 97 | |
| | 5 | |
| | P 38.21 | |

Hour-angle $3^h\ 52^m\ 45^s$ ($6^s$ too small.)

*Ex.* 3. Lat. 51° 10′ N., Dec. 19° 27′ N., Alt. 37° 51′. Required the hour-angle.

| | | |
|---|---|---|
| 51° 10′ and 19° 27′ | M 169.1 | N 43.8 |
| Alt. 37° 51′ | Factor 61.34 | P 103.7 |
| | 10146 | (diff.) 59.9 |
| | 169 | |
| | 51 | |
| | 6 | |
| | P 103.72 | |

Hour-angle $3^h\ 32^m\ 45^s$ ($3^s$ too small.)

*Ex.* 4. Lat. 47° 3′ N., Dec. 22° 37′ N., Alt. 8° 20′. Required the hour-angle.

| | | |
|---|---|---|
| 47° 3′ and 22° 37′ | M 158.8 | N 44.7 |
| Alt. 8° 20′ | Factor 14.49 | P 23.0 |
| | 1588 | (diff.) 21.7 |
| | 635 | |
| | 63 | |
| | 14 | |
| | P 23.00 | |

Hour-angle $6^h\ 50^m.12^s$ ($4^s$ too great.)

## VII. Altitudes.

### I. Correction of an Observed Altitude.

*At Sea.*—The *apparent* alt. is deduced from the observed alt. by applying to it the index corr., dip, and in certain cases the semi-diameter.

The *true* alt. is the app. alt. corrected for the effects of refraction and parallax. On shore, where an artificial horizon is used, the dip does not enter into the calculation.

When the altitude is less than 10°, the mean refraction in Table V. should be corrected by Table VI., if a thermometer and barometer are at hand. For precision, this is always necessary.

#### (1.) *To correct the Sun's Altitude.*

*At Sea.*—Apply the index corr., and add the correction of alt. Table I.

*Ex.* 1. Obs. alt. ⊙ 20° 15′ 10″; Ind. corr. +2′ 35″; Height of the eye 20 feet. Required true alt. ⊖

| | |
|---|---|
| Obs. alt. ⊙ | 20° 15′ |
| Ind. corr. | + 3 |
| Corr. of alt. | + 9 |
| True alt. ⊖ | 20 27 |

*Ex.* 2. Obs. alt. ⊙ 28° 54′; Ind. corr. + 3′; Eye 16 feet. Required true alt. ⊖

| | |
|---|---|
| Obs. alt. ⊙ | 28° 54′ |
| Ind. corr. | + 3 |
| Corr. of alt. | + 10.4 |
| True alt. ⊖ | 29 07.4 |

*Accurately.*—To the obs. alt. apply the ind. corr., subtract the dip, and, if the lower limb was observed, add the semi-diameter: this is the *apparent* central alt. Subtract the refraction, corrected for the state of the atmosphere, and add the parallax in alt. Table VIII., (the last two corrections are the sun's *correction of alt.*) The result will be the *true* central alt.

*Ex.* Suppose in the first example above given the Bar. 28.2 inches, Therm. 44°.

| | | ° | ′ | ″ |
|---|---|---|---|---|
| Obs. alt. ☉ | | 20 | 15 | 10 |
| Ind. corr. | | + | 2 | 35 |
| Dip Table IV. | | − | 4 | 17 |
| ☉'s S. D. | | + | 15 | 49 |
| | | 20 | 29 | 17 |
| Ref. Table VI. | 2′ 35″ | | | |
| Corr. Therm. | + 2 | − | 2 | 27 |
| Bar. | − 10 | | | |
| Parallax in alt. | | + | | 8 |
| True alt. ⊖ | | 20 | 26 | 58 |

When both the alt. and its supplement are observed, take half their diff.: this is the apparent zen. dist. of the centre. Add the corr. of alt. proper to the lower limb.

When the alt. is observed on an artificial horizon, apply the index corr. to the observed angle; halve the result, and apply all the preceding corrections except the dip.

### (2.) *To correct a Planet or a Star's Altitude.*

*At Sea.*—Apply the index corr., and subtract the correction Table II.

*Accurately.*—For a planet: Take the hor. par. from the N. A., and the par. in alt. corresponding from Table XIV. Proceed as for the sun, omitting the semi-diameter, which is in general insensible. A planet's *corr. of alt.* is the difference between the par. and the refraction.

For a star: As the fixed stars have neither parallax nor semi-diameter, correct their observed altitudes for index error, dip, and refraction, to obtain their true altitudes. A star's *corr. of alt.* is the refraction alone.

### (3.) *To correct the Moon's Altitude.*

*At Sea.*—Find the Greenwich date. Take out the hor. par. and semi-diameter from the N. A. and reduce them to the Greenwich date; apply the ind. corr. and subtract the dip; with the app. alt. of the limb*, and hor. par., find in Table VII. the moon's *corr. of alt.*, which add. If the *lower* limb was observed, *add* the semi-diameter; if the *upper* limb was observed, *subtract* it: the result is the true central altitude.

If it is desirable to correct the refraction for the state of the atmosphere, take from Table VI. the corr., and apply it to the *corr. of alt.* the *contrary* way to that directed.

---

* This method (given by Prof. Chauvenet, U S. N.) dispenses with the use of the augmentation of the ☽'s semi-diameter.

*Ex.* 1. May 17th, 1848, lon. 76° 32′ W. at $14^h\ 48^m$ Greenwich M. T. Obs. alt. ☽ 27° 16′; Ind. corr. −14′ 58″; Height of eye 16 feet. Required the true alt. ☽

The Hor. Par. is 54′ 14″
Semi-diameter 14′ 46″

| | | | |
|---|---|---|---|
| | ° | ′ | ″ |
| Obs. alt. ☽ | 27 | 16 | 0 |
| Ind. corr. −14′ 58″ / Dip 4 | − | 18 | 58 |
| | 26 | 57 | 2 |
| 26° 57′ and 54′ 14″ corr. of alt. | + | 47 | 4 |
| Semi-diameter | + | 14 | 46 |
| True alt ☽ | 27 | 58 | 52 |

*Ex.* 2. In the preceding example suppose the bar. 28.2, therm. 10°. Correct the moon's corr. of alt. for the state of the atmosphere.

| | | ′ | ″ |
|---|---|---|---|
| Corr. of alt. | | 47 | 4 |
| Therm. 10° | −9 | | |
| Bar. 28.2 | +6 | −3 | |
| | | 47 | 1 |

*Accurately.*—Increase the hor. par. by Table XXV. Take out the refraction for the limb observed, correct it for bar. and therm.; subtract this corrected refraction from the alt.

To the cosine of the alt. thus reduced, add the sine of the hor. par.; their sum will be the sine of the par. in alt., which is to be added to the reduced alt. to obtain the true alt. of the limb. Apply the semi-diameter, the result is the true central alt.

When the moon is referred to the opposite point of the horizon, half the diff. of the alt. and its supplement is the zenith dist. of the illuminated limb, to which the semi-diameter is to be applied the contrary way to that directed for the alt.

## II. Reduction of Two Altitudes to an Intermediate Time.

Two altitudes observed at a short interval may be reduced, by simple proportion, to an intermediate time.

Take the diff. of the alts., and the interval between the first alt. and the time proposed; the simple proportion—as the whole interval is to the diff. of alt. so is the partial interval to the corresponding change of alt., will give the change of alt. required. When the first alt. is the least, add this diff.; when it is greatest, subtract.

*Ex.* At $10^h\ 18^m\ 4^s$, observed an alt. 54° 56′; at $10^h\ 29^m\ 11^s$, observed a second alt. 55° 12′ Required the alt. at $10^h\ 23^m\ 6^s$.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ° | ′ | | h | m | s | m s |
| First alt. | 54 | 56 | Time | 10 | 18 | 4 | 5 2 |
| Second alt. | 55 | 12 | | 23 | 6 | | 11 7 |
| Diff. | | 16 | | 29 | 11 | | |

$$\frac{16' \times 5^m}{11^m 1} = 7'$$

$11^m\ 7^s : 5^m\ 2^s = 16' : 7'$, the change required.

| | | |
|---|---|---|
| | ° | ′ |
| First alt. | 54 | 56 |
| Change of alt. | + | 7 |
| Alt. required | 55 | 3 |

### III. Reduction of an Altitude to another Place of Observation.

If the observer has changed his place during the interval elapsed between the taking of two altitudes, it becomes necessary to reduce one to the place where the other was taken.

The course and distance made good in the interval is to be employed in the reduction. It is generally required to reduce the first alt. to the second place of observation, which is done in the following manner:

Take the diff. between the bearing of the body at the first obs. and the ship's course as a course, and the dist. run as a dist.; the diff. lat. corresponding is the corr. When the course employed is *less* than 90°, *add* this corr. to the first alt., when *greater, subtract* the corr.: the result is the alt. reduced to what it would have been if observed at the second place of observation.

### IV. To reduce the True to the Apparent Altitude.

#### (1.) *For the Sun, a Star, or a Planet.*

Take out the refraction to the true alt. as if for the app. alt., correcting it when requisite for the bar. and therm.; subtract the parallax in alt., add the remainder to the true alt., and subtract the correction Table XII.

#### (2.) *For the Moon.*

Find her corr. of alt. for the true alt., as if for the app. alt., and apply the correction Table XIII.

### V. To find the Altitude, the Hour-angle being given.

#### *Short Method.*

With the lat. and dec. take out M and N.

With the complement of the hour-angle to $6^h$, enter Table XXII. and take out the number corresponding.

If the lat. and dec. are of *contrary* names, take the diff. of this number and N. When the lat. and dec. are of the *same* name: if the hour-angle is *less* than $6^h$, take their *sum;* if *greater* than $6^h$, take their *diff.*

Divide this *sum* or *diff.* by M, and enter Table XXII. with this quotient, (disregarding the position of the dec. point,) and take out the angle corresponding, which is the alt. required.

*Ex.* 1. Lat. 42° 34′ S., Dec. 23° 16′ N., Hour-angle $3^h\ 34^m$. Required true alt.

42° 34′ and 23° 16′ N 39.5 M 147.8
$2^h\ 26^m$ 59.48

(diff.) 1998 | 1478
1478 | 1352
520
443
77
74
3
3

1352 gives alt. 7° 46′ (1′ too small.)

*Ex.* 2. Lat. 39° 57′ N., Dec. 16° 10′ N., Hour-angle $2^h\ 52^m$. Required true alt.

39° 57′ and 16° 10′ N 24.3 M 135.8
$3^h\ 08^m$ 73.14

(sum) 9744 | 1358
9506 | 7174
238
136
102
95
6
5

7174 gives alt. 45° 51′ (agreeing with computation by logarithms.)

*By Logarithms.*

To the cos. of the hour-angle, add the cot. of the lat.; their sum will be the tan. of $x$. If the lat. and dec. are of the *same* name, take the *sum* of $x$ and the dec.; if of *contrary* names, take their *difference*. The sum of the sec. of $x$, sine of the sum, or difference, of $x$ and the dec., and the sine of the lat., will be the sine of the true alt.

*Ex.* 1. Lat. 39° 57′ N., Dec. 16° 10′ N.; Hour-angle $2^h\ 52^m$. Required true altitude.

| | | | | | |
|---|---|---|---|---|---|
| Hour-angle | $2^h\ 52^m$ | cos. | 9.86413 | | |
| Lat. | 39° 57′ N. | cot. | 0.07696 | sine | 9.80762 |
| $x$ | 41 8 | tan. | 9.94109 | sec. | 0.17449 |
| Dec. | 16 10 N. | | | | |
| $(x + D.)$ | 57 18 | - - - - | | sine | 9.95427 |
| | | True alt. | 45° 51′ | sine | 9.93638 |

*Ex.* 2. Lat. 42° 34′ S., Dec. 23° 16′ N.; Hour-angle $3^h\ 24^m$. Required true altitude.

| | | | | | |
|---|---|---|---|---|---|
| Hour-angle | $3^h\ 24^m$ | cos. | 9.79887 | | |
| Lat. | 42° 34′ S. | cot. | 0.03693 | sine | 9.83023 |
| $x$ | 34 25 | tan. | 9.83580 | sec. | 0.08357 |
| Dec. | 23 16 N. | | | | |
| $(x - D.)$ | 11 9 | - - - - | | sine | 9.29277 |
| | | True alt. | 9° 16′ | sine | 9.20657 |

# CHAPTER IV.

## FINDING THE LATITUDE.

A case can seldom arise in practice where the latitude cannot be obtained by one of the following methods; it has not, therefore, been deemed necessary to give any rigid method of deducing the lat. from the data of a "double altitude."

### I. Latitude by Meridian Altitude.

#### (1.) *By the Sun.*

When the sun is near the meridian, continue to observe the altitude until it is found to decrease; the greatest alt. observed is the mer. alt. In very high latitudes, in summer, the sun may often be observed below the pole at midnight. In this case the least alt. is the mer. alt.

Correct the alt. Find the Greenwich date, and reduce the dec. to it. Subtract the true alt. from 90°; the remainder is the zenith dist., to be called north or south as the observer is north or south of the sun.

If the zen. dist. and dec. be both north, or both south, their sum will be the latitude, of the same name with both. If one be north and the other south, their difference will be the lat. of the same name with the greater.

When the sun is observed below the pole, add 90° to the true alt. and call the sum the zen. dist.; the lat. will be of the same name as the declination.

*Ex.* 1. Nov. 20th, 1848, lon. 76° 32′ W. Obs. mer. alt. ⊙ 31° 16′ to the S.; Ind. corr. —14′ 55″; Eye 16 feet. Required lat.

Greenwich date 20th, $5^h\ 6^m$.

| | | | | |
|---|---|---|---|---|
| (D.) p. I., N. A. | | 19° 48′ 15″ S. | diff. | +33.2 |
| | | + 2 49 | | 5.1 |
| D. | | 19 51 4 S. | | 166 |
| | | | | 3 |
| | | | | 169. |
| Obs. alt. ⊙ | 31° 16′ | | | |
| Ind. corr. | − 15 | | | |
| Corr. Table I. | + 10.5 | | | |
| True alt. | 31 11.5 | 58 48.5 N. Zen. D. | | |
| | | Lat. 38 57.5 N. | | |

*Ex.* 2. May 3d, 1848, lon. 34° W. Obs. mer. alt. ⊙ 58° 10′ to the S.; Ind. corr. + 2′; Height of eye 16 feet. Bar. 29.2 in.; Therm. 58°. Required lat.

Greenwich date, May 3d, $2^h\ 16^m$

| | | | | | |
|---|---|---|---|---|---|
| (D.) p. I. N. A. | 15° | 47′ | 33″ N. | h. diff. | +43″.5 |
| | + 1 | 39 | | | 227 |
| D. | 15 | 49 | 12 N. | | 870 |
| | | | | | 87 |
| | | | | | 30 |
| | | | | | 98.7 |

| | | | | | |
|---|---|---|---|---|---|
| Obs. alt. ⊙ | 58° | 10′ | 0″ | | |
| Ind. corr. +2 / Dip −4 | − | 2 | | | |
| Semid. | + 15 | 52 | | | |
| | 58 | 23 | 52 | | |
| Ref. 36″ / Therm. −1 / Bar. −1 | | − 34 | | | |
| Par. | | + 5 | | | |
| True alt. | 58 | 23 | 23 | 31 36 . 37 N. | Zen. dist. |
| | | | | 47 25 49 N. | Lat. |

## (2.) *By a Star, or Planet.*

The observation is the same as for the sun; but it is still more necessary to take separate alts. of a star, to avoid straining the eye to perceive its small rise or fall when near the meridian.

Take the dec. from the N. A. For a planet, reduce the hor. par. and dec. to the Greenwich date, correct the alt. by Table II., find the zenith dist., and proceed as for the sun.

*Ex.* May 17th, 1848. Obs. alt. ✳ Regulus 64° 3′ to the S.; Ind. corr. − 14′ 58″; Height of eye 16 feet. Required the lat.

| | | | | | | |
|---|---|---|---|---|---|---|
| Obs. alt. | 64° | 3′ | | True alt. | 63° | 43′ |
| Ind. corr. −15′ / Dip − 4 | − | 19 | | | 90 | |
| | 63 | 44 | | Zen. dist. | 26 | 17 N. |
| Corr. of alt. | − | 1 | | Dec. | 12 | 42 N. |
| True alt. | 63 | 43 | | Lat. | 38 | 59 N. |

## (3.) *By the Moon.*

The observation is the same as for the sun. If there is a chronometer on board, note the time when the moon was at her greatest alt.; if not, take from the N. A. the mean time of the moon's meridian passage at Greenwich, and reduce it to the time of her passage over the mer. of the ship;* to which add the longitude in time if W., or subtract it if E. The sum or diff. will be the Greenwich date.

Correct the observed alt., reduce the dec. to the Greenwich date, and proceed as with the sun.

* This reduction may be made with sufficient accuracy for nautical purposes by subtracting $2^m$ from her meridian passage at Greenwich for every 15° of East lon., or adding $2^m$ for every 15° of West lon.

*Ex.* 1. May 10th, 1848, lon. 14° W. Obs. mer. alt. ☽ 47° 53′ to the North; Height of eye 18 feet; Ind. corr. + 4′ 20″. Required lat.

| | | h | m |
|---|---|---|---|
| M. T. mer. passage 10th, | | 6 | 41.4 |
| Corr. for W. lon. | | + | 2 |
| Lon. in time | | | 56 |
| Greenwich date, 10th, | | 7 | 39.4 |

☽'s H. P. 55′ 37″ S. D. 15′ 8″

| | | | | | | |
|---|---|---|---|---|---|---|
| ☽'s (D.) at 7h | 9 | 40 | 5 N. | diff. 10m | −8.20 | |
| | − 5 | 30 | | | | 39 |
| ☽'s D. | 9 | 34 | 35 N. | | | 254 |
| | | | | | | 76 |
| | | | | | | 330. |

| | | | | |
|---|---|---|---|---|
| Obs. alt. ☽ | | 47° | 53′ | 0″ |
| Ind. corr. + 4′ 20″ | | | | |
| Dip − 4 10 | | | + 10 | |
| | | 47 | 53 | 10 |
| ☽'s corr. of alt. | | + | 36 | 26 |
| S. D. | | + | 15 | 8 |
| | | 48 | 44 | 44 |
| | | 90 | | |
| Zen. dist. | | 41 | 15 | 16 S. |
| ☽'s D. | | 9 | 34 | 35 N. |
| Lat. | | 31 | 40 | 41 S. |

*Ex.* 2. Dec. 5th, 1848, lon. 76° 32′ W. about 7h 45m P. M. At 0h 53m by chro. obs. mer. alt. ☽ 53° 16′ to the South; Ind. corr. −14′ 55″; Ht. of eye 16 feet. Required lat.

Greenwich date, 5th, 12h 53m

☽'s (H. P.) mid. 59′ 21″ ☽'s (S. D.) 16′ 10″

| | | | | | | |
|---|---|---|---|---|---|---|
| ☽'s (D.) | 0 | 24′ | 52.5 N. | diff. 10m | +11.63 | |
| | + 9 | 51.7 | | | | 53 |
| ☽'s D. | 34 | 44.2 | | | | 558.2 |
| | | | | | | 33.5 |
| | | | | | | 591.7 |

| | | | | |
|---|---|---|---|---|
| Obs. alt. ☽ | | 53° | 16′ | 0″ |
| Ind. corr. −14′ 55″ | | | | |
| Dip − 4 | | − | 18 | 55 |
| | | 52 | 57 | 5 |
| ☽'s corr. of alt. | | + | 35 | 2 |
| ☽'s S. D. | | + | 16 | 10 |
| | | 53 | 48 | 17 |
| | | 90 | | |
| Zen. dist. | | 36 | 11 | 43 N. |
| ☽'s D. | | | 34 | 44.2 N. |
| Lat. | | 36 | 46 | 27 N. |

*Degree of Dependence.*—The error of lat. is the sum or diff. of the errors of alt. and dec. The lat. by the sun, at sea, may generally be depended on within 2′; that by the moon not so near; and the lat. by a star in a dark night, not within 3′ or 4′.

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## II. By Reduction to the Meridian.

Next to the meridian altitude, in point of simplicity and accuracy, is the method of reduction to the meridian.

If, at the time of observing an alt. near the meridian, we know the hour-angle of the body observed, we may find by a simple process the diff. between the obs. alt. and the meridian alt.

The limits of this reduction are given in Table XV., and depend on the lat., dec., and the precision with which the time is known.

As the lat. by account is employed in computing the reduction, it will be necessary, when this lat. is found to be greatly in error, to repeat the work.

### (1.) *By the Sun.*

When the sun is within the limits of Table XV., observe altitudes, noting the times. When the alts. are taken very near each other, take the mean of the alts. and the mean of the times. If, however, the intervals are considerable, a separate result must be deduced for each alt.

Find the time from app. noon, or the sun's hour-angle, thus: With a watch lately regulated to App. T.—if the ship has since made *westing, subtract* the diff. lon. made good from the watch time of observation; if she has made *easting, add* the diff. lon. to the time of obs.: the result is the App. T. at ship.

By a chronometer: To the Greenwich M. T. by chro. reduce the Eq. of T., and apply it to the Greenwich M. T. as directed p. II. of the N. A.: the result is the App. T. at Greenwich. In W. lon. *subtract* the lon. in time from this Greenwich time, (increased by $24^h$, if necessary;) in E. lon. *add* it: the result (rejecting $24^h$ if it exceeds $24^h$) is the App. T. at ship.

When the App. T. of obs. is P. M., it is the sun's hour-angle; when it is A. M., subtract it from $24^h$.

Correct the alt., and find the declination.

To the log. in Table XVII. add the sine square of the hour-angle from Table XIX.; the sum is the sine of the reduction. Add the reduction to the true alt.; the result is the mer. alt. Having the mer. alt., proceed to find the lat. by the preceding method.

When the number of minutes in the reduction exceeds the number of minutes of time from the meridian, refer to Table XVI. to ascertain if it be necessary to employ the *second reduction*.

To compute the Second Reduction:—Double the sine of the reduction, and add to it the tan. of the mer. alt. and the constant 9.699; the sum is the sine of the second reduction, always to be *subtracted* from the first reduction.

*Ex.* 1. Aug. 5th, 1848, lat. by acc. 47° N., lon. by acc. 25° W. At $11^m\ 48^s$ before noon obtained true alt. ☉ 63° 54′ to the South; the dec. was 16° 55′ N. Required the latitude.

| | | | |
|---|---|---|---|
| Lat. 47°, Dec. 16° 55′ (*same* name) | | | 0.415 |
| $11^m\ 48^s$ sine sq. | | | 6.821 |
| | ° | ′ | |
| Red. | 0 | 6 | sine 7.236 |
| | 63 | 54 | |
| Mer. alt. | 64 | 0 | |
| Zen. dist. | 26 | 0 N. | |
| D. | 16 | 55 N. | |
| Lat. | 42 | 55 N | |

Repeating the work with lat. 42° 55′ gives 42° 54″. Thus the first operation reduces an error of 4° to 1′.

*Ex.* 2. Dec. 23d, 1848, lat. by acc. 8° S., lon. 10° W. At $18^m\ 45^s$ P. M. obtained true alt. ☉ 74° 16′ to the South; the dec. was 23° 27′ S. Required the latitude.

| | | | | |
|---|---|---|---|---|
| Lat. 8°, Dec. 23° 27′ | | | | 0.832 |
| $18^m\ 45^s$ sine sq. | | | | 7.223 |
| | ° | ′ | | |
| Red. | 0 | 39 | sine | 8.055 |
| | 74 | 16 | | 2 |
| | | | | 6.110 |
| Mer. alt. | 74 | 55 | tan. | 0.569 |
| | | | Const. | 9.699 |
| 2d Red. | | −1 | sine | 6.378 |
| Mer. alt. | 74 | 54 | | |
| Zen. dist. | 15 | 6 N. | | |
| Dec. | 23 | 27 S. | | |
| Lat. | 8 | 21 S. | | |

Repeating the work with this lat. as lat. by acc. gives 8° 23′, the lat. required.

### (2.) *By a Star, Planet, or the Moon.*

Obtain the hour-angle, and proceed as for the sun. If the dec. exceeds the limits of Table XVII., the tabular log. must be computed.

To compute the log. Table XVII.:—Add together 0.30103, the log. cosines of the lat. and dec., and the log. cosec. of the *diff.* of the lat. and dec. when they are of the *same* name, of their *sum* when of *contrary* names.

*Degree of Dependence.*—The error of the result is composed of that of the mer. alt., together with that of the reduction; the latter when well within the limits of Table XV. is rarely worth notice.

## III. Double Altitude of the same Body.

### *Short Double Altitude.*

If the time is not known with some precision, the method of Reduction to the Meridian cannot be employed. In such cases, two altitudes taken at a short interval, near the meridian, will furnish the requisite data. The difference of altitude in a short interval being obtained, the corresponding hour-angle may be found by computation. Compute the reduction for this hour-angle, and the latitude is obtained as in the preceding method.

If the altitudes are observed at different places, one of them must be reduced to the place at which the other was taken.* The work also must be repeated, when the computed lat. differs greatly from the lat. by account.

When both altitudes are taken on the same side of the mer., if the outer alt. fall near the limits of Table XV., the interval should exceed one-fourth of the time of that alt. from noon, and should not be less than $5^m$. When the alts. are taken on different sides, the interval may vary from $5^m$ to twice the limit in Table XV.

### *By the Sun.*

Observe an altitude and note the time, also the sun's bearing. After a proper interval, observe a second altitude and bearing. Correct the dec. for the greatest alt.; or when the alts. are equal, for noon: correct both altitudes, and also the interval by watch for the watch-rate, if it is very large.

When it is not known whether the altitudes are taken on the same or on different sides of the meridian, consider the interval as a time from noon, and compute the reduction to it. If the reduction is *less* than the diff. of alts., the observations are on the same side; if *greater*, they are on different sides; if equal to the diff. of alts., the greater altitude is a mer. alt.

### Case I.—*The Observations on the* same *side of the Meridian.*

Reduce the least alt. to the place where the greater was taken, find the diff. of the alts. and their mean.

Add together the sec. of the lat., the sine of the diff. of alts., the cosec. of the interval, the sec. of the declination, and the cos. of the mean of the alts.; the sum (rejecting the tens in the index) is the sine of the middle time between the two observations. From this time subtract half the interval: the remainder is the time from noon of the greatest alt.; to which time compute the reduction, apply it to the greatest alt., and proceed as by the preceding method.

---

* This reduction is of great consequence in this method, as the value of the result depends chiefly on the accuracy with which the diff. of the alts. has been obtained.

*Ex.* Lat. by acc. 34° 40′ S. Near noon obtained the true alt. of the ⊙ 47° 1′ 54″: after an interval of $20^m$ $12^s$ obtained true alt. 48° 1′. Both alts. A. M. Dec. at greatest alt. 6° 42′ N. Req. the latitude.

| | ° | ′ | ″ |
|---|---|---|---|
| | 48 | 1 | 0 |
| | 47 | 1 | 54 |
| Diff. alts. | | 59 | 6 |

| | ° | ′ | ″ |
|---|---|---|---|
| | 48 | 1 | 0 |
| | 47 | 1 | 54 |
| | 95 | 2 | 54 |
| Mean alt. | 47 | 31 | 27 |

| | | | |
|---|---|---|---|
| Lat. | 34° 40′ | sec. | 0.0849 |
| Diff. alts. | 59′ 6″ | sine | 8.2353 |
| Int. | $20^m$ $12^s$ | cosec. | 1.0554 |
| Dec. | 6° 42′ | sec. | 0.0030 |
| Alt. | 47° 31′ | cos. | 9.8295 |
| Mid. T. | $37^m$ $11^s$ | sine | 9.2081 |
| Half Int. | −10 6 | | |
| T. from noon | 27 5 (of gr. alt.) | | |

| | | | |
|---|---|---|---|
| Lat. 35°, Dec. 7° | | log. | 0.386 |
| | $27^m$ $5^s$ | sine sq. | 7.542 |
| Red. | ° 29 | sine | 7.928 |
| Great alt. | 48 1 | | |
| Mer. alt. | 48 30 | | |
| Zen. dist. | 41 30 S. | | |
| Dec. | 6 42 N. | | |
| Lat. | 34 48 S. | | |

The reduction being less than the diff. of alts., the observations were taken on the same side of the meridian.

## Case II. *Observations on* DIFFERENT *sides of the Meridian.*

Reduce the less alt. to the place where the greater was taken, correct both alts., and obtain the diff. of the alts.

To the ar. co. of the log. in Table XVII. add the sine of the diff. of alts., and the cosec. of half the interval; their sum is the sine of half the diff. of the times from noon of the two observations.

Subtract this half diff. from half the interval; the remainder is the time from noon of the greatest alt.

Compute the reduction to this time, and proceed as in Method II.

*Ex.* 1. Lat. by acc. 46° N. Obtained true alt. ⊙ 49° 27′ 30″ A. M.: after an interval of $34^m$ $58^s$ obtained true alt. 49° 40′ 53″ P. M. Dec. at noon 5° 28′ N.

| | | | |
|---|---|---|---|
| Lat. 46°, Dec. 5½°, | | ar. co. log. | 9.672 |
| Diff. alts., 13′ 20″ | | sine | 7.589 |
| Half int. | $17^m$ $29^s$ | cosec. | 1.118 |
| Half diff. | −5 25 | sine | 8.379 |
| T. from noon | 12 4 (of greatest alt.) | | |

| | | | |
|---|---|---|---|
| Lat. and Dec. | | log. | 0.328 |
| $12^m$ $4^s$ | | sine sq. | 6.841 |
| Red. | ° 5 | sine | 7.169 |
| Gr. alt. | 49 41 | | |
| Mer. alt. | 49 46 | | |
| Zen. dist. | 40 14 N. | | |
| Dec. | 5 28 N. | | |
| Lat. | 45 42 N. | | |

*Ex.* 2. Lat. by acc. 46° N. Obtained true alt. ⊙ 59° 57′ 12″: after $28^m$ $42^s$ true alt. 59° 20′ 30″, the ship having no way in the interval. Dec. at first alt. 15° 40′ N.

| | | | |
|---|---|---|---|
| 46° and 16° | | ar. co. log. | 9.573 |
| 36′ 40″ | | sine | 8.028 |
| Half int. | $14^m$ $21^s$ | cosec. | 1.204 |
| Half diff. | −12 40 | sine | 8.805 |
| T. from noon | 1 41 | | |

| | | | |
|---|---|---|---|
| 46° and 16° | | log. | 0.427 |
| $1^m$ $41^s$ | | sine sq. | 5.130 |
| Red. | 0′ | sine | 5.557 |

Or, the greater alt. was the mer. alt., and the lat. 45° 43′ N.

*Degree of Dependence.*—The value of the result depends principally on the diff. of alt.; the error of the lat. may be estimated by finding the effect of 1′ in the diff. of alt.

## IV. Latitude by the Change of Altitude in One Minute of Time.

When no observation has been taken for several days, the latitude by account is frequently considerably in error, and the time doubtful. This method requires neither the lat. by acc., nor the hour-angle to be known, since neither enters into the calculation. It is requisite that the change of alt. should be accurately known, but the effect of extreme accuracy vanishes with the proximity to noon; in most cases it may be depended on to an hour and a half from noon. The method is valuable, as the difference of alt. may often be correctly measured when the alts. themselves are uncertain.

### *By the Sun.*

Take two altitudes of the sun, with an interval of from eight to fifteen minutes of time; correct both altitudes, take their sum and difference, and find the change of alt. in one minute of time. Correct the declination for the middle time of observation, and if the sun bears *south* take his *north* polar distance, otherwise his south polar distance.

Add the log. of the change of alt. in one minute, (Table XVIII.) to the secant of the dec.; their sum will be the sine of A. To the cos. of A, add the cot. of half the sum of the altitudes; the sum will be the tangent of B. Take the diff. between B and the polar dist., which difference call C. The sum of cos. of C, secant of B, and sine of half sum of the altitudes, will be the sine of the latitude.

*Ex.* Lat. 49° 52′ N. by acc. About $1^h\ 30^m\ 30^s$ P. M. the true altitude of the sun was 17° 9′ 22″; at $1^h\ 42^m\ 30^s$ true alt. 16° 23′ 2″. Dec. at the mid. time, 20° 1′ 56′. Required the latitude.

| | ° | ′ | ″ | | | ° | ′ | ″ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 17 | 9 | 22 | | | 17 | 9 | 22 | | | |
| | 16 | 23 | 2 | | | 16 | 23 | 2 | | | |
| | 12 | 46 | 20 | diff. | | 33 | 32 | 24 | | | |
| Change $1^m$ = | | 3 | 52 | | Mean | 16 | 46 | 12 | | | |
| Diff. of alt. in $1^m$ | | 3 | 52 | | log. (Tab. XVIII.) | | | 9.41124 | | | |
| Sun's dec. | 20 | 2 | | | sec. | | | 0.02711 | | | |
| A. | 15 | 56 | | | sine | | | 9.43835 | | | |
| A. | | | | | cos. | | | 9.98299 | | | |
| Half sum of alts. | 16 | 46 | | | cot. | | | 0.52103 | sine | | 9.46011 |
| B. | 72 | 36 | | | tan | | | 0.50402 | sec. | | 0.52427 |
| ⊙'s N. Pol. dist. | 110 | 2 | | | | | | | | | |
| C. | 37 | 26 | | | | | | | C. cos. | | 9.89985 |
| | | | | | Lat. 50° 0′ N. | | | | sine | | 9.88423 |

*Degree of Dependence.*—When the angle A is very great, or exceeds 70°, no dependence can be placed on the accuracy of the method, unless the change of alt. in $1^m$ is accurately known. This happens to be the case only when the sun is far from the meridian, or when the lat. and dec. are nearly equal; consequently the nearer to noon the better, but it may in general be depended on to an hour and a half from noon. Should the ship change her place during the elapsed time, the first alt. should be corrected.

## V. Double Altitude of the same or different Bodies, One Altitude being near the Meridian.

### Case I. *Double Altitude of the same Body.*

When one of two altitudes is taken near the meridian, and the other when the body has a large azimuth, the hour-angle corresponding to the altitude furthest from the meridian (or the *outer* hour-angle) may be computed with sufficient accuracy, even when the lat. by account is considerably in error.

The difference of the hour-angles being afforded by the measured interval of time, the other or *inner* hour-angle is found; to which, as a time from noon, compute the reduction to obtain the mer. alt.

The inner alt. must be within the limits of Table XV., and the bearing at the outer alt. should be as near E. or W. as possible, that the error of the lat. by acc. may least affect the hour-angle.

If the computed lat. differs greatly from the lat. by acc., the work should be repeated.

#### *By the Sun.*

Obtain the correct alts. and the dec. for both observations. Reduce the least alt. to the place where the greater was taken.

With the *outer* or least alt., the lat. by acc., and the outer polar dist., compute the hour-angle, (p. 17.) The difference between this hour-angle and the interval, is the *inner* hour-angle, or mer. dist. With this compute the reduction, and apply it to the greatest alt. to obtain the mer. alt.: apply the dec. at the greatest alt., and the latitude is obtained.

*Ex.* Lat. by acc. 46° 7′ N. At about $8^h\ 10^m$ A. M. obs. ⊙ 26° 10′, sun S. E.; $3^h\ 26^m\ 35^s$ afterwards obs. ⊙ 49° 18′ to the southward. Course west; rate 6.8 knots. Ind. corr. −1′ 50″; Height of eye 16 feet. Dec. at 1st obs. 5° 13′ N.; at 2d obs. 5° 16′ N. Required the lat. at 2d obs.

| | | |
|---|---|---|
| Obs. alt. ⊙ | 26° 10″ | 49 18 |
| Ind. corr. | − 2 | − 2 |
| Corr. alt. | + 10 | + 11 |
| | 26 18 | 49 27 |
| Corr. run | − 16 | |
| 1st alt. | 26 2 | |

46° 7′ and 5° 13′ M 144.8 N 9.5
1st alt. 26° 2′ (Factor.) 43.89 P 63.55
5792 (diff.) 54.05
434
115
14
P 63.55

Hour-angle $3^h\ 49^m\ 8^s$

| | | | |
|---|---|---|---|
| Hour-angle | 3h 49m 8s | | |
| Interval | 3 26 35 | | |
| Inner hour-angle | 22 23 | sine sq. | 7.383 |
| | 46° and 5° | log. | 0.324 |
| Red. | 0° 18′ | sine | 7.707 |
| 2d alt. | 49 27 | | |
| Mer. alt. | 49 45 | | |
| Zen. dist. | 40 15 N. | | |
| 2d dec. | 5 16 N. | | |
| Lat. | 45 31 N | | |

### Case II. *Double Altitude of different Bodies.*

The preceding method applies to the case where altitudes are obtained of two different bodies, the difference of right ascensions furnishing the interval; the objects may in general be so selected as to afford the best possible result, while in the case of a single body the necessary conditions are not always a matter of choice. This method may be adopted with equal convenience in all latitudes.

The limits are the same as in the first case.

The altitudes are easily obtained by one observer. Take the alt. of the outer body, which should bear nearly E. or W. Then observe the alt. of the inner one; lastly, the outer one again, noting the times of each alt. Reduce the alts. to the same time.

If one of the bodies is the sun, moon, or a planet, find the Greenwich date, to which reduce the R. A. and declination, and for the moon her hor. par. and semi-diameter.

For a star, take the R. A. and dec. from the N. A.

Call the diff. of R. A., or its supplement, the polar angle.

Correct the altitudes, and with the outer alt. and dec. find the outer hour-angle. The diff. of the polar angle and outer hour-angle will be the mer. dist., or inner hour-angle, with which proceed as in the preceding case.*

*Ex.* Lat. by acc. 24° S. Obtained by reduction to the same instant, true alt. of Mars 29° 40′, and of Pollux 37° 39′ to the northward, near the meridian.

| | h | m | s |
|---|---|---|---|
| Mars R. A. | 11 | 53 | 17 |
| Pollux R. A. | 7 | 34 | 34 |
| Polar-angle | 4 | 18 | 43 |
| Computed hour-angle Mars | 3 | 41 | 4 |
| Hour-angle Pollux | | 37 | 39 |

Dec. Mars 3° 28′ N.
Pollux 28 27 N.

Computation of the log., Table XVII.

| ° | ′ | | |
|---|---|---|---|
| | | Const. | 0.301 |
| 28 | 27 | cos. | 9.944 |
| 24 | 0 | cot. | 9.961 |
| 52 | 27 | cosec. | 0.101 |
| | | log. | 0.307 |
| $37^m$ | $39^s$ | sine sq. | 7.828 |
| Red. 0° | 57′ | sine | 8.135 |

The mer. alt. 38° 26′ gives lat. 23° 7′ S., and, by repeating the work, 23° 11′. Hence the first process reduces an error of 50′ to 4′.

*Degree of Dependence.*—The error of the inner hour-angle is the same as that of the outer one, which when the body is near E. or W. will be very small, even when the lat. by acc. is considerably in error.

---

## VI. Double Altitude of the same Body, neither Altitude being near the Meridian.

Take two observations at an interval not less than 30 minutes, and note the times: their difference will be the elapsed time, half their sum the middle time. Correct the dec. for the middle time.

* If the moon is the body near the meridian, the dec. applied to the zen. dist. should be the dec. at the time of her meridian passage: the error in the case of any other body will be insensible.

Since the moon changes her declination very rapidly, this method does not serve well for that body.

Correct the obs. alts., and if the ship has changed her position during the elapsed time, reduce the first alt. to the place where the second was taken.

Obtain half the sum, and half the diff. of the alts., and proceed as follows:

To the cos. of half the elapsed time, add the cot. of the declination; their sum will be the cot. of angle B.

B is to be marked north or south, like the declination.

The sum of the cosec. of half the elapsed time, sec. of the dec., cos. of the half sum of the alts., and sine of the half diff. of the alts., will be the sine of C.

The sum of the sine of the declination, cosec. of B., cosec. of half the sum of the alts., sec. of half the diff. of the alts., and cos. of C, will be the sec. of Z.

Z is to be named north or south, like the bearing of the zenith.

E is the *sum* of B and Z, if of the *same* name; their *difference*, if of *contrary* names.

The sum of cos. of C, and sine of E, will be the sine of the lat.

It will be convenient to write down a form before taking out the logs.

*Ex.* February 19th, 1849, lat. by acc. 52° 20′ S., lon. 88° 45′ E. At $3^h\ 20^m\ 14^s$ P. M. the obs. alt. ⊙ 31° 52′ bearing N. W. by W.; at $5^h\ 30^m\ 14^s$ P. M. the obs. alt. ⊙ 12° 58′. The ship's course during the interval was S. W. at the rate of 7 miles per hour. Height of eye 12 feet. Required the lat.

| | h | m | s |
|---|---|---|---|
| | 3 | 20 | 14 |
| | 5 | 30 | 14 |
| Elapsed T. | 2 | 10 | 0 |
| Half E. T. | 1 | 5 | 0 |
| Mid. T. | 4 | 25 | 14 |

| | ° | ′ | |
|---|---|---|---|
| 1st alt. | 31 | 52 | |
| Corr. Table I. | + | 11 | |
| Corr. for dist. run | + | 3 | |
| | 32 | 06 | |
| | 13 | 7 | |
| 2 | 18 | 59 | |
| Half diff. | 2 | 29 | 30 |

| | ° | ′ |
|---|---|---|
| 2d alt. | 12 | 58 |
| | + | 9 |
| | 13 | 7 |
| | 32 | 6 |
| 2 | 45 | 13 |
| Half sum | 22 | 36 | 30 |

| | ° | ′ | ″ | | ″ |
|---|---|---|---|---|---|
| (D.) | 11 | 12 | 9 | S. | + 53.7 |
| | | + 1 | 20 | | 1.5 |
| D | 11 | 13 | 29 | S. | 80.7 |

| | | | | | |
|---|---|---|---|---|---|
| Half Elapsed T. $1^h\ 5^m$ | cos. | 9.98229 | cosec. | 0.55311 | |
| ⊙'s D. 11° 13′ | cot. | 0.70266 | sec. | 0.00838 | sine 9.28896 |
| B. 11° 40′ 15″ S. | cot. | 0.68495 | | | cosec. 0.69402 |
| Half sum of alts. 22° 36′ 30″ | cos. | 9.96527 | | | cosec. 0.41518 |
| Half diff. of alts. 9° 29′ 30″ | sine | 9.21723 | | | sec. 0.00599 |
| C. cos. 9.92018 | C. sine | 9.74399 | | | cos. 9.92018 |
| | | | | | Z. sec. 0.32433 |
| Z. 61 42 47 S. | | | | | |
| E. 73 23 02 | sine | 9.98147 | | | |
| Lat. 52° 52′ 30″ S. | sine | 9.90165 | | | |

*Degree of Dependence.*—No rule can be given by which to estimate the errors of this method. It is similar to Bowditch's first method, and is applicable in the same cases; it cannot be depended on when the sun passes the meridian near the zenith of the observer.

# CHAPTER V.

## FINDING THE TIME.

### I. By a Single Altitude.

The hour-angle, or meridian distance, of any heavenly body is readily determined, if the latitude of the observer, and the altitude and declination of the body observed are known. The sun is the most convenient for determining time, as it can be at once deduced from his hour-angle. In the case of any other body, it is necessary to make an allowance for the difference of their hour-angles, which is the difference of their right ascensions at the time of observation.

All the precepts under the head of Taking Observations should be carefully attended to, and, when circumstances will permit, the altitude should be observed when the body bears nearly E. or W., because errors whether of lat. or the alt. affect the hour-angle least when the body is on the prime vertical. The alt. should not be less than 6° or 8°, and when the bar. and therm. are not at hand, not less than 15° or 20°.

#### (1.) *By an Altitude of the Sun.*

Observe a set of alts. when the body is at a proper distance from the meridian, noting the times by the chronometer. Note also the bar. and therm., if accuracy is desired.

Reduce the sun's declination, and the Eq. of T. to the Greenwich date, correct the alt., and obtain the sun's polar distance.

Add together the alt., lat.,* and polar dist.; take half their sum, and from it subtract the alt.

Add together the sec. of the lat., the cosec. of the polar dist., the cos. of the half sum, and the sine of the half sum minus the alt.: half their sum will be the sine of half the hour-angle.

When the sun is to the west of the mer., (or P. M.,) the hour-angle is the App. Ast. time: when east of the mer., (or A. M.,) subtract the hour-angle from $24^h$ to obtain the App. Ast. time reckoned on the preceding day.

Apply the Eq. of T. as directed p. I. of the N. A. to the App. T.; the result is the Mean time at ship when the observation was taken.

---

* For convenience of working to whole minutes, increase or diminish the lat. by acc. 1′, so as to make the sum of the lat., alt., and polar dist. even.

The diff. between the time by chronometer (corrected for the original error and accumulated rate) and the mean time at ship, is the longitude; west if the chronometer time is *greatest*, east if it is *least*.

At sea the observation itself is seldom sufficiently accurate to require the alt., lat., or polar dist. to seconds: the nearest minute will, in general, be sufficient. If the *sum* is *odd*, and greater than 170°, take the cos. and sine to the half minute, or 30″, using Table XXVII.

*Ex.* 1. January 15th, 1848, in latitude 23° 30′ S., lon. by acc. 127° 40′ W. About $9^h\ 30^m$ A. M. obs. alt. ⊙ 55° 6′, when the chronometer showed $6^h\ 8^m\ 45$. The error of the chro. on Greenwich time, determined December 2d, 1847, was $5^m\ 7^s$ slow, with a gaining daily rate of $3^s.6$. Height of the eye 18 feet; Ind. corr. + 1′ 48″. Required the App. and Mean times of obs.; also the longitude.

| | | | |
|---|---|---|---|
| From Dec. 2d to Jan. 15th is | | 44 days | |
| | | 3.6 | |
| | | 158.4 | |
| Prop. p. to $6^h$ | | .9 | |
| Acc. rate | | 159.3 | |
| | h | m | s |
| Chro. at obs. | 6 | 8 | 45 |
| Error 2d Dec. | | + 5 | 7 |
| Acc. rate | | − 2 | 39.3 |
| Greenwich date 15th | 6 | 11 | 13 |
| | h | | |
| | 6.2 | | |

| | | | | | |
|---|---|---|---|---|---|
| ⊙'s (D.) | ° 21 | ′ 13 | ″ 43 S. | h. diff. | − 27.6 |
| | | − 2 | 51 | | 6.2 |
| ⊙'s D. | 21 | 10 | 52 S. | | 166 |
| | | | | | 5 |
| | | | | | 171. |

| | | | | |
|---|---|---|---|---|
| (E.) | m 9 | s 33.07 | h. diff. | + 0.88 |
| | | + 5.46 | | 6.2 |
| E. | 9 | 38.53 | | 528 |
| | | | | 18 |
| | | | | 5.46 |

(Additive to App. time.)

| | | | | |
|---|---|---|---|---|
| Obs. alt. ⊙ | ° 55 | ′ 6 | | |
| Ind. corr. | | + 2 | | |
| Corr. of alt. | | + 11 | | |
| True alt. | 55 | 19 | | |
| Latitude | 23 | 30 | sec. | 0.037602 |
| Polar dist. | 68 | 49 | cosec. | 0.030384 |
| | 147 | 38 | | |
| Half sum | 73 | 49 | cos. | 9.445155 |
| Diff. | 18 | 30 | sine | 9.501476 |
| | | | | 2\|19.014617 |
| | h | m | s | |
| Half h.-angle | 1 | 15 | 2 | sine 9.507308 |
| | | | 2 | |
| Mer. dist. | 2 | 30 | 4 E. | |
| | 24 | | | |
| App. T. 14th | 21 | 29 | 56 | (or, $9^h\ 29^m\ 56^s$ A. M 15th.) |
| E. | | + 9 | 39 | |
| Mean time | 21 | 39 | 35 | |
| Chro. + $24^h$ | 30 | 11 | 13 | |
| Lon. in time | 8 | 31 | 38 | or, 127° 54′ 30″ W.* |

At sea, unless the observation is remarkably good, the short method of calculating the hour-angle (see p. 17) will be sufficiently accurate. Thus, Ex. 1:—

| | | |
|---|---|---|
| 23° 30′ and 21° 11′ | M 117.0 | N 16.9 |
| Alt. 55° 19′ Factor | 82.23 | P 96.20 |
| | 9360 | (diff.) 79.30 |
| | 234 | |
| | 23 | |
| | 3 | |
| | P 96.20 | |

| | h | m | s |
|---|---|---|---|
| 79.30 gives hour-angle | 2 | 30 | 8 |
| | 24 | | |
| App. Ast. time | 21 | 29 | 52 |
| E. | | + 9 | 39 |
| Mean time | 21 | 39 | 31 |
| Chro. + $24^h$ | 30 | 11 | 13 |
| Lon. in time | 8 | 31 | 42 |
| | or, | 127° 55′ 30″ W. | |

* Longitude may be turned into time, or vice versa, by Table XXVIII., (see Ex. of Tables.)

*Ex.* 2. May 16th, 1848, lat. 38° 58′ 50″ N., lon. by acc. 76° 32′ W., about $3^h\ 26^m$ P. M. Observed the alt. of the ☉ 41° 22′ 19″ at $8^h\ 29^m\ 36^s.5$ by a chronometer, the error of which on May 1st was fast $6^s.2$, losing daily $1^s.87$. Height of eye 16 feet; Ind. corr. — 14′ 58″. Required App. and Mean time, and the longitude by chronometer.

| | h | m | s | | s |
|---|---|---|---|---|---|
| Chron. at obs. | 8 | 29 | 36.5 | | 1.87 |
| Error May 1st | | — | 6.2 | | 15 |
| Acc. rate | | + | 28.1 | | 187 |
| Greenwich date, 16th | 8 | 29 | 58.4 | | 94 |
| | h | | | Acc. rate | 28.1 |
| | 8.5 | | | | |

| | ° | ′ | ″ | | | | m | s | | s |
|---|---|---|---|---|---|---|---|---|---|---|
| (D.) | 19 | 11 | 41 | N. + | 33.9 | (E.) | 3 | 52.91 | + | 0.052 |
| | + 4 | 48 | | | 8.5 | | + .44 | | | 8.5 |
| D. | 19 | 16 | 29 | N. | 2712 | E. | 3 | 53.35 | | 416 |
| | | | | | 170 | | | | | 26 |
| | | | | | 288.2 | | | | | .442 |

(Sub. from app. time.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Obs. alt. ☉ | 41 | 22 | 19 | | | | | |
| Ind. corr. — 14′ 58″ / Dip — 4′ | — 18 | 58 | | | | | | |
| Semid. | + 15 | 50 | | | | | | |
| | 41 | 19 | 11 | | | | | |
| Ref. and Par. | — | | 55 | | | | | |
| True alt. | 41 | 18 | 16 | | | D. | | Cor. |
| Lat. | 38 | 58 | 50 | sec. | 0.109293 | 170 | 50″ | + 85 |
| P. dist. | 70 | 43 | 31 | cosec. | 0.025075 | 74 | 31 | — 23 |
| | 151 | 0 | 37 | | | | | |
| | 75 | 30 | 19 | cos. | 9.398600 | 815 | 19 | — 155 |
| | 34 | 12 | 3 | sine | 9.749801 | 310 | 3 | + 9 |
| | | | | 2 | 19.282769 | | 2 | — 84 |
| | | | | | 9.641384 | | | — 42 |
| | | | | | — 42 | | | |
| | h | m | s | | | | | |
| Half hour-angle | 1 | 43 | 52.3 | sine | 9.641342 | | | |
| | | | 2 | | | | | |
| Mer. distance | 3 | 27 | 44.6 W. | or, App. time. | | | | |
| E. | — 3 | 53.4 | | | | | | |
| Mean time | 3 | 23 | 51.2 | | | | | |
| Chro. | 8 | 29 | 58.4 | | | | | |
| Lon. in time | 5 | 6 | 7.2 | or, 76° 31′ 48″ W. | | | | |

This example has been worked to seconds to show the method. (See Ex. of Tables.)

### (2.) *By an Altitude of a Star.*

The observation is the same, and is to be taken under the same restrictions as for the sun.

Correct the alt., and take from the N. A. the star's R. A., declination, and the Sid. T. at mean noon, for the given day.

Compute the star's hour-angle as in the preceding case. When the star is W. of the mer. *add* the hour-angle to the star's R. A.; when W., *subtract* it from the R. A., (increased by $24^h$ if necessary:) the result is the R. A. of the mer., from which the mean time is found by (5.), p. 15.

If the App. time is required, find the Greenwich date, to which reduce the Eq. of T., and apply it as directed p. II. of the N. A.

*Ex.* May 17th, 1848, lat. 38° 59′ N., lon. 76° 32′ W. About $9^h\ 45^m$ P. M. obtained true altitude of Regulus 37° 33′ 36″ W. of the mer., when the chronometer showed $2^h\ 47^m\ 23^s$ Greenwich time. Required the Mean time of observation.

R. A. Regulus $10^h\ 0^m\ 17^s.3$; Dec. 12° 42′ 18″ N.; Sid. T. at Mean noon $3^h\ 41^m\ 13^s.95$.

| | | | | | |
|---|---|---|---|---|---|
| Alt. | 37° | 34′ | | | |
| Lat. | 38 | 58 | sec. | 0.109395 | |
| P. dist. | 77 | 18 | cosec. | 0.010757 | |
| | 153 | 50 | | | |
| | 76 | 55 | cos. | 9.354815 | |
| | 39 | 21 | sine | 9.802128 | |
| | | | | 19.277095 | |
| | h | m | s | | |
| Half h.-angle | 1 | 43 | 10 | sine | 9.638547 |
| | | | 2 | | |
| Hour-angle | 3 | 26 | 20 W. | | |

| | h | m | s |
|---|---|---|---|
| Hour-angle | 3 | 26 | 20 W. |
| R. A. ✳ | 10 | 0 | 17 |
| R. A. of Mer. | 13 | 26 | 37 |
| Red. S. T. at n. | 3 | 43 | 40 |
| Sid. interval | 9 | 42 | 57 |
| Mean time | 9 | 41 | 21.5 |

### (3.) *By an Altitude of the Moon or a Planet.*

The observation is the same as for the sun. Since the R. A. and dec. of the moon change very rapidly, this observation is of greater value, as the Greenwich date is more accurately known. An error of $1^m$ in the Greenwich date will produce about $2^s$ error in the moon's reduced R. A.

Find the Greenwich date, to which reduce the moon's R. A. and declination, hor. par., and semi-diameter.

Correct the altitude, compute the hour-angle, and proceed as for a star.

*Ex.* June 13th, 1848, lat. 38° 59′ N., lon. by acc. 76° 32′ W., about $6^h\ 15^m$ P. M. At $11^h\ 17^m\ 19^s$ by a chronometer $28^s.9$ slow of Greenwich time, obs. alt. ☽ 16° 36′ 30″ E. of the mer. Ind. corr. −1′ 47″; Height of eye 16 feet. Required the mean time of obs.

| | | | | | | |
|---|---|---|---|---|---|---|
| Greenwich date 13th | h 11 | m 17 | s 47.0 | | | |
| | h 11.3 | | | | | |
| H. P. 54′ 13″ | Semid. 14′ 46″ | | | | | |
| Sid. T. at Mean noon | h 5 | m 27 | s 40.97 | | | |
| ☽'s (R. A.) at $11^h$, | h 15 | m 15 | s 50.41 | m s +2 0.14 | | |
| | | | +36 | 120.14 | | |
| R. A. | 15 | 16 | 26.41 | .3 | | |
| | | | | 36.0 | | |
| ☽'s (D.) | ° 13 | ′ 55 | ″ 49.9 S. | +62.8 | | |
| | +1 | 53 | | 18 | | |
| D. | 13 | 57 | 43 S. | 63 | | |
| | | | | 50 | | |
| | | | | 113. | | |

| | | | | | |
|---|---|---|---|---|---|
| Obs. alt. ☽ | ° 16 | ′ 36 | ″ 30 | | |
| I. c. −1′ 47″ / Dip −4 | −5 | 47 | | | |
| App. alt. | 16 | 30 | 43 | | |
| Corr. of alt. | +48 | 45 | | | |
| Semid. | −14 | 46 | | | |
| True alt. | 17 | 04 | 42 | | |
| Lat. | 38 | 59 | | sec. | 0.109395 |
| P. dist. | 103 | 58 | | cosec. | 0.013033 |
| | 160 | 2 | | | |
| | 80 | 1 | | cos. | 9.238953 |
| | 62 | 56 | | sine | 9.949623 |
| | | | | | 19.311004 |
| | h 1 | m 47 | s 35 | sine | 9.655502 |
| | | | 2 | | |
| Hour-angle | 3 | 35 | 10 E. | | |
| ☽'s R. A. | 15 | 16 | 26 | | |
| R. A. mer. | 11 | 41 | 16 | | |
| Red. S. T. n. | 5 | 28 | 31 | | |
| Sid. interval | 6 | 12 | 45 S. | | |
| Mean time | 6 | 11 | 43.9 | | |

*Degree of Dependence.*—At sea, the alt. and lat. are always uncertain; the polar dist. of the moon is also liable to considerable error if the Greenwich date is not well known, and the time is liable to three causes of error. The error of the time

may be made up of the sum of these three errors; but, in general, some compensation will take place. The polar dist. of the sun will seldom be sufficiently in error to affect the result, but the lat. is in all cases doubtful. The effect of 1′ error in the lat., alt., or polar dist., may be computed by the method p. 55.

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## II. By Equal Altitudes.

The altitude of a body which does not change its declination, varies at the same rate while rising on the E. side of the meridian, as while falling on the W. side. In the case of the sun, the middle point of time, or the mean of the observed times of equal altitudes A. M. and P. M., is apparent noon. The declination of the sun changing sensibly in large intervals, equal alts. A. M. and P. M. do not correspond to equal hour-angles; and the middle time must be corrected by a quantity called the Equation of Equal Altitudes.

This method may frequently be employed at sea with advantage, when the sun was not visible at a proper time to furnish the data for obtaining the time by a single alt.; nor does it require the lat. or alt. to be known with precision.

The value of the method depends on the observation of the same alt. A. M. and P. M., without regard to the precise measure of it: instrumental errors, therefore, do not affect the observation. It is also independent of the terrestrial refraction, provided this remains unchanged in the interval.

At sea, the observation itself is not sufficiently accurate to require a correction of the interval for the change of declination; but a correction is generally necessary for the change of place in the interval between the observations. No correction is required when the course in the interval has been E. or W.; but when the ship changes her lat., she approaches to, or recedes from the sun, and the same alt. does not correspond to the same time from noon.

Within the tropics the altitude changes rapidly, even when the body is near the meridian, and the interval may generally be small. In high latitudes the method is less useful.

### (1.) *At Sea.*

Observe the sun's alt. soon before noon, noting the time by chro.: note the instant of the same alt. in the afternoon. Or, several equal alts. may be obtained at each observation.

Take the mean of the times at the two observations: this is the time by chronometer of apparent noon at the place of the observer, if the ship has not changed her place in the interval. When the latitude changes, this is the approximate time of noon.

To correct for the change of latitude:—Add together the sec. of the alt., cos. of the dec., and sine of half the interval; their sum is the sine of the azimuth.

To the constant 0.301 add the log. of the diff. lat. in minutes, the sec.* of the

---

* By request of the author this formula was investigated by Prof. Chauvenet, who discovered an important error in Raper's rule, which is here corrected.

lat., and the cot. of the azimuth; the sum is the log. of the correction in seconds of time.

When the ship has *approached* the sun in the interval, *subtract* this corr. from the middle time by chro.; when she has *receded* from the sun, *add* it: the result is the time by chro. of noon at the place of the ship at the middle time.

In W. lon., the middle time by chro. (corrected for the error) is the lon. in time. In E. lon., $12^h$ — the middle time, is the lon.

*Ex.* At sea, lat. 4° S., lon. by acc. 34° W. Course S. W. true; rate 7½ knots. Obs. alts. of the sun to the northward. Chro. slow $55^m\ 44^s$. Dec. 23½° S. Required the lon.

| Chro. A. M. | | |
|---|---|---|
| h | m | s |
| 12 | 29 | 57 |
| | 30 | 53 |
| | 31 | 45 |
| 12 | 30 | 52 Mean |

| Alt. ⊙ |
|---|
| ° ′ |
| 59 44 |
| 50 |
| 55 |

| Chro. P. M. | | |
|---|---|---|
| h | m | s |
| 2 | 8 | 39 |
| | 7 | 37 |
| | 6 | 45 |
| 2 | 7 | 40 |
| | 30 | 52 |
| Middle time by chro. | 1 | 19 16 |
| Error | | +55 44 |
| Local noon by chro. | 2 | 15 0 |

The distance run in $1^h\ 37^m$ is 12 m.; Diff. lat. made good 8′.5.

| | | | |
|---|---|---|---|
| Alt. | 60° | sec. | 0.301 |
| Dec. | 23½° | cos. | 9.962 |
| Half int. | $48^m\ 30^s$ | sine | 9.322 |
| Azim. | 22½° | sine | 9.585 |

| | | | |
|---|---|---|---|
| Const. | | | 0.301 |
| Diff. lat. | 8′.5 | log. | 0.929 |
| Lat. | 4° | sec. | 0.001 |
| Azim. | 22½° | cot. | 0.383 |
| | h m s | | |
| Corr. + | 0 0 41 | log. | 1.614 |
| | 2 15 0 | | |
| Lon. in time | 2 15 41 W. | | |

In this case the sun is to the northward, and the course southerly, or the ship has *receded* from the sun.

*Degree of Dependence.*—The effect of an error of 1′ in one of the alts. is half the time due to 1′ change of alt. To find the error due to an error of 1′ in the diff. lat. made good, divide the correction obtained by the diff. lat.; in the preceding example 1′ error causes $5^s$ error in the correction.

## (2.) *On Shore.*

The method of Equal Altitudes surpasses in accuracy all others at command of the navigator, for ascertaining the local time and rating a chronometer. Should the longitude of the observer be doubtful, the absolute error on Greenwich time cannot be determined with certainty; but the difference of errors, or rate, will admit of accurate determination. In such a case, should the rate determined differ but in a slight degree from a previous rate determined at some other place, the longitude of which is better known, the error brought up from the last determination may be assumed to be correct.

This method depends principally on the *hourly change* of declination, and does not require the lat., or even the declination itself, to any great degree of accuracy.

Any observation, by means of which the rate of a chronometer is to be determined, should be taken with great care, and freed from all errors, except those incident to the method. Some of the precepts heretofore laid down will be repeated as particularly applicable to this observation.

The altitudes should be taken on an artificial horizon, when the sun bears nearly east or west; the altitudes then vary most rapidly, and the use of the artificial horizon halves all errors of observation. After taking several, say six, observations, the screens should be reversed, and another set taken with the other face towards the observer, to rid the observation of the errors of the screens. As the sun may not be equally bright morning and evening, colored eye-pieces to the telescope should be used instead of the colored shades of the sextant, (see page 6.)

*To take the Observation.*—In the morning, when the sun is at a sufficient altitude, bring the images nearly in contact in the horizon, clamp the index, and note the instant of contact: take altitudes at every 10′ until a sufficient number are obtained. In the afternoon, the altitudes will follow in the reverse order. Inexperienced observers frequently find it difficult to set the index, and again bring the images into the field of the telescope in time to save the observation; such observers can avoid the difficulty by noting the contact of both limbs and the centre, leaving the index clamped at the altitude until the afternoon, when the limbs will follow in the reverse order.

If several sets of observations are taken morning and evening, the difference of the mean times of corresponding sets of observations, will be the *elapsed time:* half their sum will be the *middle time.* The hours are counted in numeral succession, so that if some of the observations are taken before $12^h$ by the chronometer, and others after $12^h$, the next hour to $12^h$ must be called $13^h$, &c.

If the declination does not change, the middle time will be the time of apparent local noon by chronometer. As, however, it generally changes during the interval, the middle time must be corrected by the Equation of Equal Altitudes.

The following simple notation will be more explicit than any rule:—

L = Latitude of the observer, + when North, − when South.
D = Sun's declination, + when North, − when South.
$d$ = Hourly change ⊙'s dec., + when *towards* North, − when *towards* South.
E = Eq. of T., + when additive to App. T., − when subtractive.
T = Middle time by chronometer.
To = Time of App. noon by do. = $T + a + b$.
$a$ = $d$ A tan. L.
$b$ = $d$ B tan. D.
Error of chro. = To − ($0^h$ + E).

*To compute the Equation of Equal Altitudes.*

Take the log. of $d$ in seconds from Table XXIII., log. A from Table XX., and the tan. of the latitude; mark the logs. with the same signs as the quantities they represent: their sum will be the log. of $a$. The sum of log. $d$, log. B from Table XX., and the tan. of the declination, will be the log. of $b$. $a$ and $b$ are to be taken from Table XXIII. in seconds and tenths, with their signs: their sum if both + or both −, their difference if one is + the other −, added to, or subtracted

from, the middle time as indicated by the sign, will give the time of apparent local noon by chronometer. Apply the Eq. of T. as indicated by the sign, and we obtain the error of the chro. on local time.

If the chro. is regulated to Greenwich time, take the diff. of the error on local time, and the lon. in time; the remainder is the error of the chro.: in W. lon. *fast*, if the chro. time is *greatest—slow*, if *least;* in E. lon. the error of the chro. is *slow*, if the chro. time is *greatest—fast*, if *least.*

*Ex.* July 1st, 1848, lat. 40° 41′ N., lon. 74° W. obtained the following observations of equal altitudes on an artificial horizon.

A. M.

COMPARISONS.

| | h | m | s |
|---|---|---|---|
| Chro. | 11 | 54 | 6.5 |
| Watch | 6 | 58 | 0 |
| Diff. | 4 | 56 | 6.5 |

A. M. gain $1^s.5$ in $31^m$
Interval to obs. $15^m$

$31^m : 15^m = 1^s.5 : 0^s.7$

P. M.

COMPARISONS.

| | h | m | s |
|---|---|---|---|
| Chro. | 9 | 35 | 40 |
| Watch | 4 | 40 | 0 |
| Diff. | 4 | 55 | 40 |

P. M. gain $1^s.5$ in $25^m\ 30^s$
Interval to obs. $14^m\ 30^s$

$25^m.5 : 14^m.5 = 1^s.5 : 0^s.8$

| | h | m | s |
|---|---|---|---|
| Chro. | 0 | 25 | 5 |
| Watch | 7 | 29 | 0 |
| Diff. | 4 | 56 | 5 |

| | h | m | s |
|---|---|---|---|
| Chro. | 10 | 1 | 8.5 |
| Watch | 5 | 5 | 30 |
| Diff. | 4 | 55 | 38.5 |

Watch A. M.

| h | m | s | |
|---|---|---|---|
| 7 | 12 | 40 | |
| " | 13 | 7 | |
| " | 13 | 33 | |
| 7 | 13 | 6.3 | |
| 4 | 56 | 5.8 | |
| 0 | 9 | 12.1 | Chro. at obs. |
| 9 | 50 | 12.7 | |
| 9 | 59 | 24.8 | |
| 4 | 59 | 42.4 | T. |
| | | +2.6 | $(a+b)$ |
| 4 | 59 | 45.0 | To. |
| | | −3 32.7 | E. |
| 4 | 56 | 12.3 | Error on local time. |
| 4 | 56 | 0 | Lon. in time. |
| | | 12.3 | Chro. *fast* on Greenwich time. |

$2\odot$

| ° | ′ | |
|---|---|---|
| 55 | 10 | |
| " | 20 | |
| " | 30 | |

(E.) $+3^m\ 30^s.5 + 0^s.48$
$+2.2 \quad 5.$
E. $+3\ 32.7 \quad 2.40$

(D.) $+23^\circ\ 6'\ 8'' \quad -10''.93$
$-55 \quad 5.$
D. $+23\ 5\ 13 \quad 54.7$

Watch P. M.

| h | m | s | |
|---|---|---|---|
| 4 | 55 | 0 | |
| " | 54 | 33.5 | |
| " | 54 | 7 | |
| 4 | 54 | 33.5 | |
| 4 | 55 | 39.2 | |
| 9 | 50 | 12.7 | Chro. at obs. |
| 0 | 9 | 12.1 | |
| 9 | 41 | 0.6 | Elapsed T. |

H. diff. $10''.93$ log. 1.0386 −
Lat. tan. 9.9343 +
A. log. 9.5292 −
0.4921 +

$a + 3^s.10$
$b - .47$
$(a+b) + 2.63$

D. tan. 9.6296 +
B. log. 9.0042 +
$b - 0^s.47$ 9.6724 −

1.0386 −

The method of Equal Altitudes is capable of considerable precision, and as small errors in the time affect the rate considerably, it is desirable to remove all possible errors. A change of refraction may take place in the interval, which will affect the second alt., particularly when the alts. are low.

To correct for the diff. of refractions:—Find the corrections of the refractions at both observations for the bar. and therm.: if these corrections differ, we have the proportion—as 10′ is to the change of refraction, so is the time it takes the alt. to

change 10′ to the correction: *half* of which is to be *added* to the middle time, if 1st ref. is *greater ;* to be *subtracted,* if *least.*

*Degree of Dependence.*—The error of the equation of equal altitudes caused by the use of the hourly diff. as given in the N. A., though theoretically liable to a slight inaccuracy, will not affect the tenths of seconds. Small errors in the lat. and dec. are insensible. The observation should be corrected for the effects of variations in the refraction whenever practicable.

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## III. Rating the Chronometer.

The error of a chronometer is the quantity by which it is fast or slow of the mean time at the meridian for which it is regulated, which we have heretofore supposed to be that of Greenwich.

The error may be determined—First, If the chronometer has a known rate, by multiplying the rate by the number of days elapsed since the last determination of the error, and adding the product to, or subtracting it from, the former error as the rate is gaining or losing, and the error fast or slow. Secondly, If the longitude of the place is well determined, by finding the error of the chro. on mean local time, and thence, as explained in the preceding article, the error on Greenwich time. Thirdly, The lunar observation, or an observation of the moon's altitude, affords the absolute time at Greenwich; the difference of this time and that shown by the chronometer, is the error of the latter. This last method can only be depended on within certain limits explained under the proper head.

The rate of a chronometer is the difference of its daily errors. It is called *gaining* when it goes too *fast, losing* when too *slow.*

As the rate is liable to great irregularities, it should be obtained as often as practicable, that the degree of dependence on the *mean* rate may be known. If left at an observatory, or instrument-maker's, to be rated, frequent comparisons should be required. The rate may be obtained—First, By finding the absolute error on the time at place, by observation, at an interval of a few days. Secondly, By direct comparison of the *interval of time* shown by the chronometer, with that measured by a clock, or another chro., of known rate, or with the motion of a star. Thirdly, By the difference of longitude.

### I. By Comparison with the Absolute Time, or Longitude.

#### (1.) *By the Time.*

The best method of obtaining the time, at command of the navigator, is by equal altitudes. Next in value, is the same alt. repeated in the same part of the day. The times determined by A. M. and P. M. sights on the same day do not agree, either

at sea or on shore, as the *same* errors of lat. and alt. affect the *hour-angles* in the *same* way, or the *times* in *different* ways.

The difference of the errors found by either of the above-mentioned methods, divided by the number of days in the interval between the observations, will be the mean daily rate. When the error is found to have changed from slow to fast, or fast to slow, the rate is the sum of the errors, divided by the number of days elapsed.

When the chronometer is *fast*, either of Greenwich time, or of the time at the place of the observer, if the error is *increasing*, the rate is *gaining*; if *decreasing*, the rate is *losing*. When the chro. is *slow*, if the error is *increasing*, it is *losing*; if *decreasing*, it is *gaining*.

When the ship leaves any place, and after an interval not much exceeding a fortnight, returns to it again, the error of the chronometer accumulated in her absence is found directly, by comparing the time obtained by observations taken at her departure and at her return. The error thus found affords the actual *sea-rate*, which, as the sea and harbor rates seldom agree, is much to be preferred to the harbor-rate.

The following example of the daily variations to which the best chronometers are liable, is selected from the report of Lt. Maury, Superintendent of the National Observatory. The performance of this chronometer was far within the limits required for acceptance, yet more than one half of the chronometers sent to the Observatory for trial are rejected.

(Trial.) Eight-Day Chronometer, No. 1495.

| Days. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| | s | s | s | s | s | s | s | s | s |
| 1 | −4.7 | −4.1 | −4.2 | −5.3 | −5.2 | −6.0 | −5.2 | −5.9 | −7.1 |
| 2 | 4.2 | 4.1 | 5.7 | 4.8 | 5.7 | 6.0 | 5.7 | 6.4 | 6.1 |
| 3 | 3.7 | 4.6 | 5.2 | 4.8 | 5.7 | 5.5 | 5.2 | 6.4 | 6.1 |
| 4 | 4.7 | 4.6 | 5.2 | 4.8 | 6.2 | 6.0 | 5.7 | 6.4 | 6.1 |
| 5 | 4.7 | 5.1 | 5.7 | 4.8 | 5.7 | 6.0 | 6.2 | 5.4 | 6.1 |
| 6 | 4.7 | 4.6 | 5.2 | 4.8 | 5.2 | 5.5 | 5.7 | 5.4 | 5.6 |
| 7 | 4.7 | 4.6 | 5.2 | 5.3 | 5.2 | 6.0 | 5.7 | 5.9 | 6.1 |
| 8 | 4.7 | 4.1 | 4.7 | 5.3 | 4.7 | 6.0 | 5.2 | 5.4 | 6.1 |
| 9 | 5.7 | 4.6 | 5.2 | 5.3 | 5.2 | 6.0 | 5.2 | 6.2 | 6.1 |
| 10 | 5.1 | 5.1 | 5.7 | 4.8 | 5.7 | 5.5 | 4.7 | 5.9 | 6.1 |

This table of the rates for each of the first ten days for nine months, in a fixed position, and subject to but slight variations of temperature, will show the little dependence to be placed in a single chronometer, subject to continual shocks and jars from the motion of the ship, and liable to injury from the often careless manner in which they are transported from the observatory to the ship.

### (2.) *By the Longitude.*

When on making a *well-determined* point of land, the lon. by chro. does not agree with the actual position of the ship, the rate may be corrected for the acceleration or retardation of the sea-rate upon the harbor-rate. Great caution must, however, be observed in making this correction, and it would perhaps be preferable to take the new error of the chronometer as a fresh point of departure, without

changing the rate; the new rate found being applied as a *guard-rate*, and the position of the ship plotted off daily in the positions given by the old and corrected rates.

The best check upon the irregularities of the chronometer, at sea, is the lunar observation, which should be taken whenever practicable; but the method of *rating* chronometers by lunars cannot be recommended, and is of doubtful utility. They are of great use for detecting a gross *error* in the longitude by chronometer, caused by a considerable change of rate; but when such a change of rate has been discovered, it would be unsafe to trust to it for the remainder of the voyage. The chro. will in such cases, serve to keep up the connection of positions.

Should the chronometer stop, or run down, at sea, it should be set a-going immediately on the discovery, and its error on Greenwich time found by a series of lunars, or alts. of the moon, as explained in the next chapter. The rate it had when it stopped may be assumed as the present rate, until a new rate can be assigned, and will probably be nearer the truth than any rate which can be assigned to it by the lunar observation at sea.

## II. By Comparison of Intervals of Time.

### (1.) *By a Clock.*

The chronometer being compared at different times with a clock, or another chronometer, of which the rate is known, the difference of the errors for the intervals is obtained, and thence the rate is deduced. The following method is adopted when it is left at an observatory, or instrument-maker's, to be rated.

Eight-Day Chronometer, No. 1495.

| Date. | Clock. | Chronometer. | Diff. | Daily rate of | |
|---|---|---|---|---|---|
| | | | | Clock. | Chron. |
| | h m s | h m s | s | s | s |
| | | 5 1 52.5 | | | |
| June 1 | 12 00 00 | 48.0 | −4.5 | +0.3 | −4.2 |
| 2 | . . . | 42.0 | 6.0 | 0.3 | 5.7 |
| 3 | . . . | 36.5 | 5.5 | 0.3 | 5.2 |
| 4 | . . . | 31.0 | 5.5 | 0.3 | 5.2 |
| 5 | . . . | 25.0 | 6.0 | 0.3 | 5.7 |

### (2.) *By a Star.*

A star returns to the same point of the heavens $3^m\ 55^s.91$ of mean time earlier every mean solar day; consequently, the observation of the same altitude, or the transit of the star over the wire of a fixed telescope, determines the rate. The altitude should be considerable, in order to avoid errors of refraction, and the telescope should be nearly in the meridian.

To find the rate, multiply $3^m\ 55^s.91$ by the number of days elapsed, and subtract the product from the first time noted; the remainder is the time the chronometer

would show if it went uniformly, and the difference between this time and the time it shows is the diff. of error for the interval.

### III. By Difference of Longitude.

When the error of the chronometer upon the time at any place is compared with the error on the time at another place, the difference of these two errors is the diff. lon. in time between these two places. Hence, if the diff. lon. is accurately known, the sea-rate may easily be obtained. A table of chronometric differences of lon. would furnish the means of rating a chronometer by this method, but it has not been deemed necessary to insert it in this treatise.

# CHAPTER VI.

## FINDING THE LONGITUDE.

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### I. By the Chronometer.

Longitude being merely relative, can only be ascertained with reference to the meridian of some other place; and, as it is measured by time, it is most conveniently determined by comparison of the time at the place of the observer, with the time at some other place.

All ships are (or should be) furnished with one or more chronometers, regulated to the time at some place arbitrarily assumed as the first meridian. American and English navigators usually assume that of Greenwich. The mean time at the place being found, as directed in the preceding chapter, take the difference between this time and the time by chronometer, corrected for the original error and accumulated rate.

When the time by chronometer is *least*, the lon. is E.; when the *greatest*, the lon. is W. The time at the place of the observer is liable to certain errors, and the daily rate of the chronometer liable to sudden changes; the error of the longitude is made up of the sum or diff. of the two. As one chronometer therefore is not to be depended upon as fixing the position in longitude, it is usual to furnish national vessels with three, or more. A daily comparison between these chronometers, will check any irregularities of either; as it may be inferred if one differs from the other two, and they agree, that it has jumped to the extent of the difference: while if there is but one on board, it cannot be ascertained whether its rate is steady or irregular, until the error has become sufficiently great to exceed the limits of accuracy of which the lunar observation is susceptible.

An account should be kept in a book, in which the error on Greenwich time is entered as fast or slow, and the rate applied to this as it is gaining or losing.

If the lon. or Greenwich time be obtained, by lunar or otherwise, and it does not agree with the rate allowed, a new rate must be assigned from a careful consideration of circumstances.

The following is a convenient form in which to note the daily errors: when a new error and rate have been determined, they should be placed opposite the date. The daily variation of the quantity in the column headed "Diff." should equal the sum or difference of the daily rates, or they do not run regularly. *Fast* errors and *gaining* rates are marked +; *slow* errors and *losing* rates, —.

Comparison of Chronometers at 8 a. m.

| Date. | No. 1495. | Error. | Rate. | Diff. 1495 & 1713 | No. 1713. | Error. | Rate. |
|---|---|---|---|---|---|---|---|
| | h m s | h m s | s | h m s | h m s | m | s |
| Jan. 1 | 5 6 0 | +2 14 0 | −5.3 | 2 16 49.5 | 2 49 10.5 | −2 49.5 | −1.7 |
| 2 | 5 0 0 | +2 13 54.7 | | 2 16 45.9 | 2 43 14.1 | −2 51.2 | |
| 3 | 5 4 10 | +2 13 49.4 | | 2 16 42.3 | 2 47 27.7 | −2 52.9 | |

For want of room on this page but two are compared together. The same mode may be adopted with any number; taking the diff. between each chro. and the first, any irregularities will at once become apparent.

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## II. By the Lunar Observation.

The true distance of the moon from the sun, planets, and certain of the fixed stars, at the end of every three hours, being given in the N. A., it is evident that we have only to ascertain the distance in order to determine the Greenwich date at the observation.

The distance in the N. A. is, however, the angular distance at the centre of the earth; and before we can compare the measured with the true distance, we must reduce the former to what it would have been if taken at the centre: this reduction is called *clearing the distance.*

The refraction of the sun, a star, or a planet, being greater than its parallax in altitude, causes the body to appear *above* its true place; but the moon's parallax in alt. being greater than the refraction, causes her to appear *below* her true place. It is, therefore, evident that the difference between the true and apparent distances depends almost entirely on the *corrections of altitude*, and will in general be greatest when the distance is small, and the difference of the alts. considerable. The *corr. of alt.* depending in a great measure on the temperature and density of the atmosphere, it is important to note the height of the bar. and therm., and correct the mean refraction. The alts. should never be less than 5° or 6°; and when the bar. and therm. are not noted, not less than 12° or 15°. An error of several minutes in the alt. will but slightly affect the result. If the time is well known, the altitudes of the moon and other bodies observed may often be calculated with greater accuracy than they can be observed, particularly at night; the short method p. 20 will in general be sufficiently accurate.

All the precepts under the head of "Observing Lunar Distances" should be carefully attended to.

The method of preparing the data for computation by either of the following methods is the same.

Having obtained the mean of the alts. and distances observed, find the Greenwich date; to which reduce the hor. par. and semid. Augment the semid. by Table X., and increase the par.* by Table XXV.

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* If the par. is increased, the correction for the spheroidal figure of the earth (p. 51) must not be neglected.

Correct the observed distance for ind. error, and apply the semid.; the result is the apparent distance. Find the app. alts. of the centres by applying the ind. corr., dip, and semid.

If the sun, or a planet, is one of the bodies, find the *corr. of alt.* by subtracting the par. in alt. from the refraction. A star's *corr. of alt.* is the refraction alone. Find the moon's *corr. of alt.* by Table VII. Correct these for the therm. and bar. whenever these instruments are at hand.

Find the true distance by either the first or second method, to which, if the observation was a reliable one, apply the special corrections noticed p. 51.

*To obtain the Greenwich Mean Time.*—Find in the N. A. the two distances between which the true dist. falls. Take out the first of these, and set it down under the true dist., and write against it its prop. log. taken from the N. A. Take the difference between the two distances thus set down, and add its log. sine (from Table XXVI.) to the prop. log. taken from the N. A.; the sum is the log. sine* of a portion of time to be added to the time of the distance taken from the N. A. to obtain the Greenwich mean time.

The difference between the time by lunar and the chronometer time of observation will be the *error of chro., fast* if the chro. time is *greatest, slow* if *least.* The longitude may thence be found as directed in the preceding article.

### (1.) *Short Method.*

In this method the object is to find the correction of the apparent distance due to the corrections of altitude of each body.

The moon is always seen *below*, and the sun, or star, *above* their true places. When the moon is the lower of the two bodies, it is evident that raising her will diminish the apparent distance; or, her corr. of dist. must be subtracted: when the moon is the higher body, it is generally additive. When the sun or star is the lower body, lowering it will increase the app. dist.; its corr. of dist. is therefore additive, but in general subtractive when it is the uppermost body.

When the moon's alt. is near 80°, or the dist. is so small as 20°, M and N do not vary proportionally, and this method is not sufficiently accurate. For distances greater than 50°, if M and N are carefully interpolated, it will not differ from the true dist. more than 2″ or 3″.

I. *For the Moon's Corr. of Dist.*—With the moon's app. alt. and the diff. of the app. dist. from 90°, take out M and N from Table XXI., (see Ex. of Tables.)

Enter Table XXII. with the sun's or star's alt. and take out the factor corresponding, by which multiply M; point off two more decimals than the product contains, and call the product P.

When the dist. is *greater* than 90°, take the *sum* of N and P.

When the dist. is *less* than 90°, take the *diff.* of N and P.

Multiply this *sum* or *difference* by the moon's corr. of alt. in minutes and tenths,

* It was not considered necessary to insert a Table of prop. logs. to be used in the above calculation. (See Ex. of Table XXVI.)

and cut off the last two integral figures of the product as decimals of a minute. This is the moon's corr. of dist.

II. *For the Moon's 2d Corr.*—Enter Table XXIV. with the app. dist. and the moon's *corr. of alt.*, and take out the seconds. Enter again with the *corr. of dist.*, and take out the seconds. The difference of these quantities is the 2d corr.

III. *For the Sun's, or Star's, Corr. of Dist.*—With the sun's or star's app. alt. and the diff. of the app. dist. and 90°, take out M and N.

With the moon's alt. take from Table XXII. the factor corresponding, by which multiply M and obtain P.

Take the *diff.* or *sum* as before directed, and multiply it by the sun's, or star's, corr. of alt. in seconds. This gives the corr. of dist. required, also in seconds.

Apply these corrections to the app. dist. as follows, to obtain the true distance.

| Distance *less* than 90°. | | | | Distance *greater* than 90°. | |
|---|---|---|---|---|---|
| ☽ corr. of dist. | | ⊙ or ✳ corr. of dist. | | ☽ corr. of dist. | ⊙ or ✳ corr. of dist. |
| When P is | | When P is | | *subtract.* | *add.* |
| less than N *add.* | greater than N *sub.* | less than N *sub.* | greater than N *add.* | | |
| ☽ 2d corr. of dist. *add.* | | | | ☽ 2d corr. of dist. *sub.* | |

*Ex.* 1. (Dist. *greater* than 90°.) In lat. 40° N., the observed distance of the ⊙ and ☾ was 108° 10′ 29″; Obs. alt. ⊙ 6° 15′ 19″; Obs. alt. ☽ 54° 31′ 4″. Height of the eye 16 feet. Therm. 26°; Bar. 30.7 in. (H. P. 55′ 10″; ☽'s semid. 15′ 7″; ⊙'s semid. 16′ 15″.) Required the true distance.

| | | | |
|---|---|---|---|
| Obs. dist. ⊙ ☾ | 108° | 10′ | 29″ |
| Semid. ⊙ | | +16 | 15 |
| " ☽ | | +15 | 7 |
| Aug. | | + | 12 |
| App. dist. | 108 | 42 | 3 |
| Co-dist. | 18 | 42 | |
| ☽'s H. P. | | 55′ | 19″ |
| Red. for Lat. (T. 25.) | | | +4.5 |
| True H. Par. | | 55 | 23.5 |

| | | | |
|---|---|---|---|
| Obs. alt. ☽ | 54° | 31′ | 4″ |
| Dip | | − | 4 |
| Semid. | | −15 | 19 |
| App. alt. ☽ | 54 | 11 | 45 |

☽'s corr. of alt.

| | | |
|---|---|---|
| Par. 55′ gives | 31′ | 30″ |
| " 24″ " | | +14 |
| 2′ alt. | | − 2 |
| Bar. | | − 0.8 |
| Therm. | | − 2.5 |
| | 31 | 39 |
| | 31′.6 | |

| | | | |
|---|---|---|---|
| Obs. alt. ⊙ | 6° | 15′ | 19″ |
| Dip | | − | 4 |
| Semid. | | +16 | 15 |
| App. alt. ⊙ | 6 | 27 | 34 |

⊙'s corr. of alt.

| | | |
|---|---|---|
| Ref. | 7′ | 58″ |
| Therm. | | +23 |
| Bar. | | + 8 |
| Par. | | − 9 |
| | 8 | 20 |
| | 500″ | |

☽'s Corrections.

| | | | |
|---|---|---|---|
| ☽'s alt. 54° 12′ co-dist. | M | 180.5 | N 46.9 |
| ⊙'s alt. 6° 28′ (Factor) | | 11.25 | P 20.3 |
| | | 1805 (sum) | 67.2 |
| | | 181 | 31.6 |
| | | 36 | 2016 |
| | | 9 | 67 |
| | P | 20.31 | 40 |
| | | | 21.23 |

☽'s corr. of dist. 21′ 14″

110° and 32′, 3″ } −2″ ☽'s 2d corr.
21′, 1″ }

⊙'s Correction.

| | | | |
|---|---|---|---|
| ⊙'s alt. 6½° and co-dist. | M | 106.2 | N 3.8 |
| ☽'s alt. 54° 12′ (Factor) | | 81.11 | P 86.1 |
| | | 8496 (sum) | 89.9 |
| | | 106 | 500″ |
| | | 11 | 449.5 |
| | | 1 | |
| | P | 86.14 | |

⊙'s corr. of dist. 7′ 30″

| | | | |
|---|---|---|---|
| App. dist. | 108° | 42′ | 3″ |
| ☽'s corr. of dist. | | −21 | 14 |
| ☽'s 2d corr. | | − | 2 |
| ⊙'s corr. of dist. | | + 7 | 30 |
| True dist. | 108 | 28 | 17 |

That the student may compare the accuracy of the two methods, the two following examples have been selected from Bowditch's Navigator. The true distance is found to be the same by both methods.

*Ex.* 2. (Dist. *less* than 90°.) May 12th, 1836, about 1 P. M., in lon. by acc. 4° E., at $0^h\ 41^m$ by chronometer, obtained app. alt. ☉ 39° 55′; app. alt. ☽ 27° 48′; app. dist. 46° 37′ 15″. (Co-dist. 43° 23′.) H. P. 56′ 03″. Required the error of the chronometer on Greenwich time.

☽'s Corrections.

| | M | N |
|---|---|---|
| ☽'s alt. and co-dist. | 156.0 | 50.1 |
| ☉'s alt. (Factor.) | 64.17 | P 100.1 |
| | 9360 | (diff.) 50.0 |
| | 624 | 47.7 |
| | 16 | 23.85 |
| | 11 | |
| | P 100.11 | |

☽'s corr. of dist. 23′ 51″

| | | |
|---|---|---|
| 56′ | 47′ | 44″ |
| 3″ | | + 3 |
| 8′ alt. | | − 3 |
| | 47 | 44 |
| | 47′.7 | |

☽'s corr. of alt.

19″, 5″ } + 14″ ☽'s 2d corr. of dist.

☉'s Correction.

| | M | N |
|---|---|---|
| ☉'s alt. and co-dist. | 179.9 | 79.5 |
| ☽'s alt. (Factor | 46.64 | 83.9 |
| | 7196 | (diff.) 4.4 |
| ☉'s corr. of alt. | 1079 | 63″ |
| | 107 | 264 |
| Ref. 1′ 9.5 | 7 | 13 |
| Par. −6.5 | P 83.89 | 2.77 |
| 63″ | | |

☉'s corr. of dist. 3″

| | | | | | |
|---|---|---|---|---|---|
| App. dist. | 46° | 37′ | 15″ | | |
| ☽'s corr. of dist. | | −23 | 51 | | |
| 2d corr. | | + | 14 | | |
| ☉'s corr. | | + | 3 | | |
| True dist. | 46 | 13 | 41 | | |
| By N. A. at $0^h$ | 46 | 34 | 02 | prop. log. | 3097 |
| | | 20 | 21 | log. sine | 7.7723 |
| | h | m | s | | |
| Gh. time | 0 | 41 | 31 | log. sine | 8.0820 |
| Chro. | 0 | 41 | 0 | | |
| Chro. slow | | | 31 | | |

*Ex.* 3. (Dist. *greater* than 90°.) August 27th, 1836, in lon. by acc. 25° W. About $50^m$ A. M., at $2^h\ 20^m\ 36^s$ by a chro. supposed $8^m\ 6^s$ slow of Greenwich time, obtained app. alt. ☽ 22° 31′; app. alt. planet Mars 10° 26′; app. dist. 113° 49′ 2″. (H. P. 59′ 16″.) Required the error of the chro. on Greenwich time.

☽'s Corrections.

| | M | N |
|---|---|---|
| ☽'s app. alt. and co-dist. | 118.3 | 18.3 |
| ☆'s alt. (Factor.) | 18.11 | P 21.4 |
| | 1183 | (sum) 39.7 |
| | 946 | 52.5 |
| | 12 | 1985 |
| | 1 | 79 |
| | P 21.42 | 20 |
| | | 20.84 |

☽'s corr. of dist. 20′ 50″

| | | |
|---|---|---|
| 59′ | 52′ | 14″ |
| 16″ | | +15 |
| | 52 | 29 |
| | 52′.5 | |

☽'s corr. of alt.

11″, 2 } −9″ ☽'s 2d corr.

☆'s Correction.

| | M | N |
|---|---|---|
| ☆'s app. alt. and co-dist. | 111.1 | 8.1 |
| ☽'s alt. (Factor.) | 38.30 | P 42.6 |
| | 3333 | (sum) 50.7 |
| ☆'s corr. of alt. | 889 | 303″ |
| | 33 | 1521 |
| Ref. 5′ 8″ | P 42.55 | 15 |
| Par. −5 | | 153.6 |
| 5 3 | | |
| 303″ | | |

☆'s corr. of dist. 2′ 33″

| | | | | | |
|---|---|---|---|---|---|
| App. dist. | 113° | 49′ | 02″ | | |
| ☽'s corr. of dist. | | −20 | 50 | | |
| ☽'s 2d corr. | | − | 9 | | |
| ☆'s corr. of dist. | | + 2 | 33 | | |
| True dist. | 113 | 30 | 36 | | |
| By N. A. at $12^h$ | 114 | 55 | 6 | prop. log. | 2455 |
| | 1 | 24 | 30 | log. sine | 8.3905 |
| | h | m | s | | |
| Gh. time | 2 | 28 | 44 | log. sine | 8.6360 |
| Chro. | 2 | 20 | 36 | | |
| Error chro. slow | | 8 | 8 | | |

If in the preceding example we suppose the therm. to stand at 70°, and the bar. 29.5 inches, the ☽'s corr. of alt. will be 52′ 38″, ☆'s corr. of alt. 4′ 47″; which will give ☽'s corr. of dist. 20′ 53″, ☆'s corr. of dist. 2′ 25″, and true dist. 113° 30′ 25″; or, a diff. lon. of 4′. This method is not only as accurate as either of the methods in Bowditch's Navigator, but it admits of a correction for the state of the atmosphere. This correction cannot be applied to either the first or second method of Bowditch; the other methods, on account of their length, are seldom used.

The preceding examples have been worked out in full to show the method, but the following steps are all which will be required after a little practice.

*Ex.* 4. May 17th, 1848, lon. by acc. 76° 32′ W., about $9^h\ 40^m$ P. M. At $2^h\ 41^m$ by a chronometer, supposed $8^m\ 3^s$ slow of Greenwich time, obtained app. dist. ☽ and ✱ Regulus 88° 13′ 20″; app. alt. ☽ 27° 16′; app. alt. ✱ 37° 35′. ☽'s corr. of alt. 46′ 20″; ✱'s corr. of alt. 1′ 16″.

| M | N | M | N |
|---|---|---|---|
| 112.5 | 1.6 | 125.7 | 2.2 |
| 60.99 | 68.6 | 45.81 | 57.8 |
| 6750 | 67.0 | 5028 | 55.6 |
| 101 | 463 | 649 | 76. |
| 10 | 2778 | 100 | 3892 |
| 68.61 | 324 | 57.77 | 334 |
| | 31.02 | | 42.26 |

☽'s corr. 31′ 01″ ✱'s corr. 42″
2d corr. 0″

| | | | |
|---|---|---|---|
| | 88° | 13′ | 20″ |
| | | −31 | 01 |
| | | + | 42 |
| True dist. | 87 | 43 | 1 |
| | 86 | 18 | 57 .3037 |
| | 1 | 24 | 4 8.3883 |
| Gh. T. | 2 | 49 | 14 8.6920 |
| Chro. | 2 | 41 | 0 |
| Err. of chro. | | 8 | 14 |

## (2.) *Rigid Method.*

In this method the true distance is found by calculation, using the apparent distance, and also the apparent and true altitudes.

Add together the distance and *apparent* altitudes; take their half sum, and the difference between the half sum and the app. dist.; obtain also the half sum of the true alts.

Add together the secants of the *apparent* altitudes, the cosine of the half sum, (of app. alts. and dist.,) the cosine of the difference, and the cosines of the *true* alts.; take half the sum of these logs. From this half sum *subtract* the cosine of the half sum of the true alts.; the difference will be the sine of angle A.

To the cosine of A, *add* the cosine of the half sum of the true alts.; the sum will be the sine of half the true distance.

The preparation is the same as in the first method; it is therefore unnecessary to repeat it.

*Ex.* 1. (*Same as Ex.* 1. *Short Method.*) App. dist. 108° 42′ 3″; app. alt. ⊙ 6° 27′ 34″; app. alt. ☽ 54° 11′ 57″. True alt. ⊙ 6° 19′ 14″; true alt. ☽ 54° 43′ 36″.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| App. dist. | 108° | 42′ | 3″ | | | | |
| ⊙'s app. alt. | 6 | 27 | 34 | sec. | 0.002758 | + | 8 |
| ☽'s app. alt. | 54 | 11 | 57 | sec. | 0.232700 | + | 167 |
| | 169 | 21 | 34 | | | | |
| Half sum | 84 | 40 | 47 | cos. | 8.968249 | − | 1062 |
| Diff. | 24 | 1 | 16 | cos. | 9.960674 | − | 15 |
| ⊙'s true alt. | 6 | 19 | 14 | cos. | 9.997355 | − | 3 |
| ☽'s true alt. | 54 | 43 | 36 | cos. | 9.761642 | − | 107 |
| | 61 | 2 | 50 | | 2\|38.923378 | | 2\|1012 |
| | | | | | 19.461688 | | − 506 |
| | | | | | − 506 | | |
| | | | | | 19.461182 | | |
| Half sum tr. alts. | 30° | 31′ | 25″ | cos. | 9.935215 | - - - | 9.935215 |
| A. | 19 | 36 | 57 | sine | 9.525967 | cos. | 9.974035 |
| Half true dist. | 54° | 14′ | 8″ | - - - - | | sine | 9.909250 |
| True dist. | 108 | 28 | 16 | | | | |

*Ex.* 2. (*Ex.* 4. *Short Method.*) May 17th, 1848, lat. 38° 59′ N., lon. by acc. 76° 32′ W. About $9^h\ 40^m$ P. M., at $2^h\ 41^m$ by a chronometer supposed $8^m\ 3^s$ slow of Greenwich time, obs. dist. ☽ and ✱ Regulus 88° 13′ 25″; obs. alt. ☽ 27° 19′ 47″; obs. alt. ✱ 37° 53′ 50″. Ind. corr. − 14′ 58″; Height of eye 16 feet. Therm. 54°; Bar. 30.2 inches. Required the error of the chronometer.

Greenwich date 17th $14^h\ 49^m\ 3^s$.

| | | | |
|---|---|---|---|
| Obs. dist. | 88° | 13′ | 25″ |
| Ind. corr. | | −14 | 58 |
| Semid. | | +14 | 46 |
| Aug. Tab. X. | + | | 7 |
| App. dist. | 88 | 13 | 20 |

| | | | |
|---|---|---|---|
| ☽'s (H. P.) | 54′ | 8″.5 | |
| | | +1.3 | |
| Tab. XXV. | | +4.2 | |
| H. P. | 54 | 14 | |

| | | | |
|---|---|---|---|
| Obs. alt. ☽ | 27° | 19′ | 47″ |
| I. c. −14′ 58″ / Dip − 4 | | −18 | 58 |
| Semid. | | +14 | 53 |
| App. alt. | 27 | 15 | 42 |
| Corr. of alt. | | +46 | 20 |
| True alt. | 28 | 2 | 2 |

| | | | |
|---|---|---|---|
| Obs. alt. ✱ | 37° | 53′ | 50″ |
| I. c. −14′ 58″ / Dip − 4 | | −18 | 58 |
| App. alt. | 37 | 34 | 52 |
| Corr. of alt. | | −1 | 16 |
| True alt. | 37 | 33 | 36 |

| | | | | | | |
|---|---|---|---|---|---|---|
| App. dist. | 88° | 13′ | 20″ | | | |
| ☽'s app. alt. | 27 | 15 | 42 | sec. 0.051090 | + 45 | |
| ✱'s app. alt. | 37 | 34 | 52 | sec. 0.100922 | + 84 | |
| | 153 | 3 | 54 | | | |
| | 76 | 31 | 57 | cos. 9.367659 | −506 | |
| | 11 | 41 | 23 | cos. 9.990908 | − 10 | |
| ☽'s true alt. | 28 | 2 | 2 | cos. 9.945800 | − 2 | |
| ✱'s true alt. | 37 | 33 | 36 | cos. 9.899176 | − 59 | |
| Sum | 65 | 35 | 38 | 2\|39.355555 | 2\|458 | |
| | | | | 19.677777 | −229 | |
| | | | | −229 | | |
| | | | | 19.677548 | | |
| Half sum | 32 | 47 | 49 | cos. 9.924587 | - - - 9.924587 | |
| A. | 34 | 29 | 5 | sine 9.752961 | cos. 9.916073 | |
| Half dist. | 43° | 51′ | 31″.5 | - - - - | sine 9.840660 | |
| Dist. | 87 | 43 | 3 | | | |
| Corr. spheroid | | + | 3 | | | |
| True dist. | 87 | 43 | 6 | | | |
| Dist. at $12^h$ | 86 | 18 | 57 | p. log. .3037 | | |
| | 1 | 24 | 9 | sine 8.3887 | | |
| | 2 | 49 | 22 | sine 8.6924 | | |
| | 12 | | | | | |
| Gh. time | 14 | 49 | 22 | | | |
| Chro. at obs. | 14 | 41 | 0 | | | |
| Chro. slow | | 8 | 22 | | | |

Spheroidal Correction.

| | |
|---|---|
| M 103.6 | N 0.9 + |
| 23.0 | P 23.8 + |
| 2072 | A 24.7 + |
| 311 | |
| P 23.8 | |

| | |
|---|---|
| log. A | 1.393 + |
| log. S | 1.128 |
| ☽'s dec. 15° cos. | 9.985 |
| Corr. + 3″.2 | 0.506 + |

## Special Corrections.

In addition to the corrections which have been applied, to remove the effects of refraction and parallax, there are several others of minor importance, of which it is necessary to take notice when precision is required. The correction for inequality of the moon's motion involves so slight an addition to the calculation that it should always be applied.

### (1.) *Correction for the Elliptical Figure of the Disk.*

At low altitudes the refraction sensibly affects the figure of the sun or moon, and consequently the observed distance: the correction of Table XI. is to be applied.

The angle between the lunar dist. and the vertical can be estimated with sufficient accuracy by the eye. It is, however, given in the short method. With the sum or diff. of P and N, at the lower of the two bodies, enter Table XXII. and take out the angle corresponding, which is the angle required.

*Ex.* In Ex. 1. p. 47 the sum of P and N 89.9 gives in Table XXII. 64°, and the correction Table XI. 4″ subtractive.

### (2.) *Correction for the Spheroidal Figure of the Earth.*

The error arising from a neglect of this correction will seldom exceed 15″.

Increase the hor. par. by Table XXV. With the dec. of the moon, and the co-dist. taken to the nearest degree, enter Table XXI. and take out M and N. Multiply M by the factor corresponding to the sun's, or star's, dec. (Table XXII.) If the sun's, or star's, dec. is of the *same* name as the lat., mark the product +; if of *contrary* name −; and call this product P.

If the lunar dist. and the moon's polar dist. are both less, or both greater than 90°, mark N−. If one is less, while the other is greater than 90°, mark N+.

Take the *sum* of P and N, if both + or both −; their *difference*, if one is +, the other −: call this sum or diff. A, and mark it with the sign of the sum, or greater, of the quantities.

Add together the log. of A, (Table XXIII.,) log. S, (Table XXVI.,) and the cos. of the moon's dec.; their sum (rejecting 2 in the index) will be the log. of a correction in seconds to be added to, or subtracted from, the distance as indicated by the sign of A, (see Ex. p. 50.)

### (3.) *Correction for the Inequality of the Moon's Motion.*

The proportional log. in the N. A. opposite the lunar distance is the log. of the change of dist. in $3^h$; but the motion being seldom uniform, it is generally necessary to apply a correction for the difference of the prop. logs.

Take the diff. between the prop. logs. opposite the two distances in the N. A. between which the true dist. falls; with this diff. and the interval, enter the following table and take out the seconds. When the prop. logs. in the N. A. are *increasing, subtract* these seconds; when *decreasing, add* them. The result is the corrected Greenwich time.

## CORRECTION OF THE GREENWICH MEAN TIME

FOR THE SECOND DIFFERENCE OF THE LUNAR DISTANCE.

| Diff. of Prop. Logs. in the N. A. | Interval. | | | | | | | | | | Diff. of Prop. Logs. in the N. A. | Interval. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $0^h$ | | | | | | $1^h$ | | | | | $0^h$ | | | | | | $1^h$ | | | |
| | m 0 | m 10 | m 20 | m 30 | m 40 | m 50 | m 0 | m 10 | m 20 | m 30 | | m 0 | m 10 | m 20 | m 30 | m 40 | m 50 | m 0 | m 10 | m 20 | m 30 |
| | s | s | s | s | s | s | s | s | s | s | | s | s | s | s | s | s | s | s | s | s |
| 6 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 114 | 0 | 8 | 14 | 20 | 24 | 28 | 31 | 34 | 35 | 35 |
| 12 | 0 | 1 | 1 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 120 | 0 | 8 | 15 | 21 | 26 | 30 | 32 | 36 | 37 | 37 |
| 18 | 0 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 126 | 0 | 9 | 16 | 22 | 27 | 31 | 34 | 37 | 39 | 39 |
| 24 | 0 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 7 | 7 | 132 | 0 | 9 | 17 | 23 | 28 | 33 | 36 | 39 | 40 | 41 |
| 30 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 9 | 9 | 138 | 0 | 9 | 18 | 24 | 30 | 34 | 37 | 41 | 42 | 43 |
| 36 | 0 | 2 | 4 | 6 | 8 | 9 | 10 | 11 | 11 | 11 | 144 | 0 | 10 | 18 | 25 | 31 | 36 | 39 | 43 | 44 | 45 |
| 42 | 0 | 3 | 5 | 7 | 9 | 10 | 11 | 12 | 13 | 14 | 150 | 0 | 10 | 19 | 26 | 32 | 37 | 40 | 44 | 47 | 47 |
| 48 | 0 | 3 | 6 | 8 | 10 | 12 | 13 | 14 | 15 | 15 | 156 | 0 | 11 | 20 | 27 | 33 | 39 | 42 | 46 | 48 | 48 |
| 54 | 0 | 4 | 7 | 9 | 12 | 13 | 15 | 16 | 17 | 17 | 162 | 0 | 11 | 21 | 28 | 35 | 40 | 44 | 48 | 50 | 50 |
| 60 | 0 | 4 | 7 | 10 | 13 | 15 | 16 | 18 | 18 | 19 | 168 | 0 | 11 | 21 | 29 | 36 | 42 | 45 | 50 | 52 | 52 |
| 66 | 0 | 4 | 8 | 11 | 14 | 16 | 18 | 19 | 20 | 20 | 174 | 0 | 12 | 22 | 30 | 37 | 43 | 47 | 51 | 53 | 54 |
| 72 | 0 | 5 | 9 | 12 | 15 | 18 | 19 | 21 | 22 | 22 | 180 | 0 | 12 | 23 | 31 | 39 | 45 | 49 | 53 | 55 | 56 |
| 78 | 0 | 5 | 10 | 13 | 17 | 19 | 21 | 23 | 24 | 24 | 186 | 0 | 12 | 24 | 32 | 40 | 46 | 50 | 55 | 57 | 58 |
| 84 | 0 | 6 | 10 | 14 | 18 | 21 | 23 | 25 | 26 | 26 | 192 | 0 | 13 | 24 | 33 | 41 | 48 | 52 | 57 | 59 | 60 |
| 90 | 0 | 6 | 11 | 15 | 19 | 22 | 24 | 27 | 28 | 28 | 198 | 0 | 13 | 25 | 34 | 43 | 49 | 53 | 58 | 61 | 62 |
| 96 | 0 | 7 | 12 | 17 | 21 | 24 | 26 | 28 | 29 | 30 | 204 | 0 | 14 | 26 | 35 | 44 | 51 | 55 | 60 | 63 | 63 |
| 102 | 0 | 7 | 12 | 18 | 22 | 25 | 27 | 30 | 31 | 32 | 210 | 0 | 14 | 26 | 36 | 45 | 52 | 57 | 62 | 64 | 65 |
| 108 | 0 | 7 | 13 | 19 | 23 | 27 | 29 | 32 | 33 | 33 | 216 | 0 | 14 | 27 | 37 | 46 | 54 | 58 | 64 | 66 | 67 |
| | m 0 | m 50 | m 40 | m 30 | m 20 | m 10 | m 0 | m 50 | m 40 | m 30 | | m 0 | m 50 | m 40 | m 30 | m 20 | m 10 | m 0 | m 50 | m 40 | m 30 |
| | $3^h$ | $2^h$ | | | | | $1^h$ | | | | | $3^h$ | $2^h$ | | | | | $1^h$ | | | |
| | Interval. | | | | | | | | | | | Interval. | | | | | | | | | |

*Degree of Dependence.*—The true distance is affected by errors of observation and computation. An error in the distance produces about 30 times its amount in the longitude; 10″ error of distance produce about 300″, or 5′, of longitude.

The observed distance is liable to errors of observation, and those of the instrument; the latter should therefore be carefully adjusted, and the contact made in the centre of the field of the telescope.

The errors in the computation arise from the errors in the elements, and those of the method of solution.

Precision in the altitudes is not essential, as an error of a few minutes is almost insensible. If the altitudes have not been observed, they may be calculated by the short method, (p. 20.) The refraction should be corrected for the state of the bar. and therm., particularly at low altitudes, and when the bodies are in or near a vertical plane.

The errors of the short method of solution will seldom exceed 5″, and is most accurate for distances exceeding 50°.

The rigid method will give the true distance, from the data, within a single second.

## III. By the Moon's Altitude.

The Right Ascension of the moon changing with considerable rapidity, it has been proposed to determine the longitude by comparing the computed R. A. with the R. A. given in the Nautical Almanac.

As the variation of the R. A. is but about $2^m$ in an hour, or $2^s$ in $1^m$, an error of $2^s$ in the moon's hour-angle would produce the same error in her reduced R. A., and 15′ in the longitude deduced from it.

An error of 1′ of altitude, in the most favorable case, must produce an error of $4^s$ in the hour-angle, and, as the place of the sea horizon is seldom known to that degree of accuracy, it follows that at sea the result can seldom be entitled to as great a degree of confidence as the lunar observation, in which an observer seldom makes an error exceeding half a minute.

It is also necessary that the Greenwich date should be known with some precision, to avoid errors in the reduction of the moon's declination and the sidereal time at mean noon.

If, however, sufficient care be taken to free the observation from all errors other than those incident to the method, the result may at times be of service when, from a want of instruments, or a good observer, the lunar observation cannot be taken.

At sea, the uncertainty of the dip should be removed, by referring the moon, when possible, to the opposite point of the horizon, as well as to that under her.

As the altitude under such circumstances would in general be too great to give the best result, it may be preferable to observe the sun, or a star, for this latter purpose. Observe the alt. and its supplement; the diff. between their half sum and 90° is the joint correction for index error and dip, which may be applied to the observed alt. of the moon. If the half sum is *greater* than 90°, the correction is subtractive; if *less*, *additive*.

All the precepts under the head of Taking Observations, Finding the Time, &c. should be carefully attended to. The lat. should, if possible, be determined at the time of observation, to avoid the error of the reckoning.

If the mean time is not accurately known, it must be obtained by observation. An error in the local time produces an equal error in the R. A. of the mer. and the moon's R. A. deduced from it. It is therefore important that it should be accurately known.

If observations are taken on opposite sides of the mer., but on the same side of the prime vertical, the right ascensions resulting will be affected in different ways by the same errors of alt. and lat., and the true longitude will be between the two results.

Observe a set of alts., noting the time by chronometer. Find the Greenwich date, to which reduce the moon's dec., hor. par., and semid.: increase the hor. par. by Table XXV.. To the sine of the moon's polar dist. add log. S. from Table XXVI.; their sum is the log. of a correction in seconds, always to be *subtracted* from the pol. dist.

Take out the Sid. T. at mean noon for the given day. To the constant log. 0.9937 add the log. of the Greenwich date, (in hours and decimals of an hour;) their sum will be the log. of a correction in seconds of time to be added to the Sid. T. To the reduced Sid. T. add the Mean T. of obs.; the sum (rejecting $24^h$ if it exceed $24^h$) is the R. A. of the meridian.

Correct the alt. (p. 19.) Compute the hour-angle, (p. 35.)

When the moon is to the E. of the meridian, *add* her hour-angle to the R. A. of the mer., (rejecting $24^h$ if the sum exceed $24^h$.) When to the W. *subtract* the hour-angle from the R. A. of the mer., (increased, if necessary, by $24^h$;) the result is the moon's R. A.

Take the diff. (in seconds) between this R. A. and the next less in the N. A., and also the diff. of the two between which it falls. To the constant 3.5563, add the log. of the first of these diffs., and the ar-co. log. of the 2d; the sum is the log. of a portion of time (in seconds) to be added to the time at Greenwich of the least R. A., to obtain the Greenwich mean time at obs.

*Ex.* June 13th, 1848, lat. 38° 58′ 50″ N., lon. by acc. 76° 32′ W. At $1^h\ 23^m\ 22^s$ A. M. mean time and $6^h\ 29^m\ 30^s$ by chronometer, obs. alt. ☽ 17° 25′ 49″ to the W. Ind. corr. −1′ 5″; Height of eye 16 feet; Bar. 30.12 in.; Therm. 65°. Required the error of the chro.

| | | | | | |
|---|---|---|---|---|---|
| Gh. date | 18h | 29m | 30s | | |
| | 18h.493 | | | log. | 1.2670 |
| Sid. T. n. | 5 | 27 | 41 | const. | 0.9937 |
| | | +3 | 2.3 | log. | 2.2607 |
| | 5 | 30 | 43.3 | | |
| M. T. | 13 | 23 | 22 | | |
| R. A. mer. | 18 | 54 | 5.3 | | |

| | | | | |
|---|---|---|---|---|
| (H. P.) | 54′ | 13″.1 | + | 6″.3 |
| | | +3.4 | | 6.5 |
| Tab. XXV. | | +4.2 | | 378 |
| H. P. | 54 | 20.7 | | 32 |
| | | | | 41.0 |
| | | | | 3.4 |

Semid. 14′ 47″

| | | | | | |
|---|---|---|---|---|---|
| (D.) | 14° | 38′ | 31″.6 | S. | +58″.6 |
| | | +2 | 52.8 | | 29.5 |
| D. | 14 | 41 | 24.4 | S. | 1172 |
| | | | | | 527 |
| P. dist. | 104° | 41′ | 24″ | | 29 |
| | | | | | 172.8 |

| | | |
|---|---|---|
| P. dist. | sine | 9.986 |
| | log. S. | 1.128 |
| Corr. | −13″ | 1.114 |

Corrected P. dist. 104° 41′ 11″

| | | | | | | |
|---|---|---|---|---|---|---|
| Obs. alt. ☽ | 17° | 25′ | 49″ | | | |
| I. c. −1′ 5″ / Dip −4′ | | −5 | 5 | | | |
| | 17 | 20 | 44 | | | |
| Ref. 3′ 5″ / Therm. −4 / Bar. +1 | | −3 | 2 | | | |
| | 17 | 17 | 42 | | 54′ 21″ sine | 8.1988 |
| | | | | | - - - cos. | 9.9799 |
| ☽'s corr. of alt. | | +51 | 53 | | - - - sine | 8.1787 |
| Semid. | | +14 | 47 | | | |
| True alt. | 18 | 24 | 22 | | | |
| Lat. | 38 | 58 | 50 | | sec. | 0.109293 + 85 |
| P. dist. | 104 | 41 | 12 | | cosec. | 0.014420 + 7 |
| | 162 | 4 | 24 | | | |
| | 81 | 2 | 12 | | cos. | 9.192734 −160 |
| | 62 | 37 | 50 | | sine | 9.948388 + 55 |
| | | | | | | 19.264835 2\|13 |
| | | | | | | 9.632417 − 6 |
| | | | | | | −6 |
| | h | m | s | | | |
| Half h.-angle | 1 | 41 | 36.2 | | sine | 9.632411 |
| H.-angle | 3 | 23 | 12.4 | | | |
| R. A. mer. | 18 | 54 | 5.3 | | | |
| | 15 | 30 | 52.9 | | const. | 3.5563 |
| R. A. at 18h | 15 | 29 | 54.7 | | 58s.2 log. | 1.7649 |
| at 19h | 15 | 31 | 55.9 | | 121s.2 log. | 7.9166 |
| | | 28 | 49 | | 1729s log. | 3.2378 |

| | h | m | s |
|---|---|---|---|
| | 18 | | |
| Gh. T. of obs. | 18 | 28 | 49 |
| Chro. | 18 | 29 | 30 |
| Chro. fast | | 41 = 10′.3 of lon. | |

*Degree of Dependence.*—This is determined by the effects produced on the hour-angle by given errors in the alt., lat., and polar dist.

*To find the error of time caused by* 1′ *error of alt.*

Take from column D in Tab. XXVIII. the diff. to 100″ of the cos. and sine employed, and divide twice their sum by the diff. to 100″ of the sine of half the hour-angle; the quotient will be the error in seconds of time, corresponding to 1′ of alt. When the alt. is too *great*, the hour-angle is too *small*; when the alt. is too *small*, the hour-angle is too *great*.

*To find the error of time caused by* 1′ *error of lat.*

Take the diff. for 100″ of the sec. employed, and double it; to this add the diff. for 100″ for the sine, and subtract that for the cosine: double the remainder, and divide it by the D to 100″ of the sine of half the hour-angle.

If the lat. and dec. are of the *same* name and the lat. too *great*, the hour-angle will be too *great*; if of *contrary* names and lat. too *great*, the hour-angle will be too *small*.

*To find the error of time caused by* 1′ *error of polar dist.*

Take the diff. to 100″ of the cosec., double it; to this add the D to 100″ of the cos.: subtract the D to 100″ of the sine; double the remainder, and divide it by the D to 100″ of the sine of half the hour-angle.

If the lat. and dec. are of the *same* name, and the polar dist. too *great*, the hour-angle will be too *great*; if of *contrary* names, and the polar dist. too *great*, the hour-angle will be too *small*.

Thus, in the preceding example, we have—

Error of 1′ of alt.

| | | | |
|---|---|---|---|
| 81° 2′ | D. to cos. | 1336 | |
| 62 38 | sine | +109 | |
| | | 1445 | |
| | | 2 | |
| 443 | 2890 | 6ˢ.5 | |
| | 2658 | | |
| | 232 | | |
| | 222 | | |

Error of 1′ of lat.

| | | | |
|---|---|---|---|
| 38° 59′ | D. to sec. | 170×2=340 | |
| 62 38 | sine | +109 | |
| | | 449 | |
| 81′ 2″ | cos | 1336 | |
| | | 887 | |
| | | 2 | |
| 443 | 1774 | 4ˢ. | |
| | 1772 | | |

Error of 1′ p. dist.

| | | | |
|---|---|---|---|
| 104° 41′ | D. to cosec. | 55×2=110 | |
| 81 2 | cos. | +1336 | |
| | | 1446 | |
| 62° 38′ | sine | 109 | |
| | | 1337 | |
| | | 2 | |
| 443 | 2674 | 6ˢ. | |
| | 2658 | | |

An error of 1ˢ of R. A., in the preceding example, would produce an error of 32ˢ, or 8′ of lon.; and as 1′ error of alt. would produce 6ˢ.5 of R. A., or 52′ of lon., it follows that great care is required in both the observation and computation to produce a reliable result.

# EXPLANATION OF THE TABLES.

It is not deemed necessary to enter into any detailed explanations of the tables, as all persons into whose hands this work will fall are presupposed to have had some practice in the use of logarithmic and other tables; such tables as differ from those in general use are, however, clearly explained.

### Table I. *For correcting the Sun's Altitude, at Sea.*

This table contains the correction of the sun's alt. for the effect of semid., dip, refraction, and par. in alt. The table is to be entered with the height of the eye at the top, and the altitude at the side; the correction corresponding *added* to the observed alt., corrected for index error, if there be any, will give the true alt. of the sun's centre.

### Table II. *For correcting a Planet or a Star's Altitude, at Sea.*

This table contains a correction always to be *subtracted* from the observed alt. to obtain the true alt. The table is to be entered as in the preceding case.

### Table III. *Sun's Semidiameter.*

This table contains the sun's semidiameter, and is given for convenience in certain cases.

### Table IV. *Apparent Dip of the Sea-Horizon.*

This is the angular depression of the sea-horizon below the horizontal plane, in ordinary states of the atmosphere, and when the sea and air are of the same temperature. This correction is subject to great variations, depending on the diff. of temperature of the sea and air, (see p. 5.)

### Table V. *Mean Astronomical Refraction.*

The refraction is given for the barometer 30 inches, and Fahrenheit's thermometer at 50°, according to Mr. Ivory. By means of the diff. to 10′ of alt. the correction to the minute is readily obtained.

TABLE VI. *Correction of the Mean Refraction for the Height of the Thermometer and Barometer.*

The table is entered with the alt. at the top, and the height of the tnerm. or bar. at the side. The precept at the head of the column shows how the correction is to be applied to the mean refraction.

TABLE VII. *The Moon's Correction of Altitude.*

This table contains the correction to each minute of horizontal parallax, and every 10′ of alt.; for a mean state of the bar. and therm.

*To correct for Seconds of Parallax.*—From the columns on the right side of the page against the alt. take out the seconds, which are to be *added* to the correction.

*To correct for Minutes of Alt.*—Take out the seconds from the extreme right of the page, and apply them as there directed.

*To correct for the Bar. and Therm.*—Take the corrections from Table VI., but apply them the *contrary way* to that directed.

*Ex.* Moon's app. alt. 35° 37′; Hor. Par. 57′ 32″; Therm. 34°, Bar. 30.4 inches. Required the correction of alt.

| | | | ° | ′ |
|---|---|---|---|---|
| 35° 30′ and 57′ | | | 45 | 3 |
| Parts for 32″ | + 26 | | | |
| " 7′ | − 4 | | + 22 | |
| Therm. 34° | − 3 | | | |
| Bar. 30.4 | − 1 | | − 4 | |
| Correction required | | | 45 | 21 |

TABLES VIII., IX.

These tables require no explanation.

TABLE X. *Augmentation of the Moon's Semidiameter.*

This table is entered with the moon's semid. at the top, and her alt. at the side; the seconds corresponding are to be added to her semid. from the N. A. to obtain the semid. at the place of the observer.

TABLE XI. *Correction of the Lunar Distance for the Contraction of the Vertical Semidiameter.*

This table is entered with the alt. at the side, and the angle between the vertical line passing through the body and the line joining the bodies at the top, (see p. 51.)

TABLES XII., XIII. *For converting True into Apparent Altitudes.*

These tables contain the further correction necessary after applying the corr. of alt., (see p. 20.) Their use may be avoided by entering Tables V. and VII. with the approximate app. alt. and taking out the correction corresponding, which is to be applied to the true alt.

### Table XIV. *Parallax in Altitude of the Planets.*

The table is entered with the planet's horizontal parallax at the top, and its altitude at the side.

### Table XV. *Limits of the Reduction to the Meridian, at Sea.*

This table shows the time before or after noon at which the sun's altitude may be observed, so that the *reduction* shall not be in error more than 2′ when the *time* is $1^m$ in error. The table, therefore, shows the limits of this method for common practice at sea.

If the time be in error, or doubtful, $2^m$, $3^m$, &c., the reduction will at the limit be in error, or doubtful, 4′, 6′, &c.; and if we require the reduction to be true to 2′, we must take the observation at a time from noon $\frac{1}{2}$ or $\frac{1}{3}$ of that in the table.

### Table XVI. *Value of the Reduction at which the Second Reduction amounts to* 1′.

This table contains against each mer. alt. under 85°, that value of the reduction at which the second reduction amounts to 1′, and therefore shows at once whether it is necessary or not to compute the latter.

***Ex.*** Suppose the mer. alt. 68° and the 1st reduction computed to be 47′, then the error of omitting the 2d red. cannot amount to 1′; but if the 1st red. were 54′, the omission of the 2d red. would cause an error of more than 1′.

### Table XVII. *Logarithms for computing the Reduction to the Meridian, at Sea.*

The table is entered with the declination at the top, and the latitude at the side. The cases omitted are not eligible.

When the lat. exceeds 62°, or the dec. 23°, the logarithm must be computed; thus:—Add together 0.30103, the cosines of the lat. and dec., the cosec. of the *difference* of the lat. and dec. when of the *same* name, the cosec. of the *sum* if of *contrary* names.

### Table XVIII. *Logarithms of the Change of Alt. in* $1^m$.

This table is entered with the minutes at the top, and the seconds at the side, of the change of alt. in one minute of time.

It contains the log. of the change of alt. in minutes, divided by 15.

### Table XIX. *Sine Square.*

This table contains twice the log. sine of half the arc. It is to be entered with the minutes of time at the side, and the seconds at the top.

It is given to be used in computing the reduction to the meridian, (see p. 24.)

### Table XX. *Equations of Equal Altitudes.*

This table, furnished by Prof. Chauvenet, U. S. N., is employed in computing the equation of equal altitudes, (see p. 36.) It is to be entered with the hour of the elapsed time at the top, and the minute at the side, taken to the nearest minute.

### Table XXI. *Spherical Traverse Table.*

This table is to be entered with the *lesser* of two given angles at the top, and the *greater* at the side; to take out M and N for 64° and 15°, enter with 15° at the top and 64° at the side, then M is found 236.2, and N 54.9.

Interpolation for a fraction of a degree is easy, because M and N always increase. In general M and N can be taken at sight; for example, to find M for 59° 47′ and 66° 18′, that is, $59\frac{3}{4}°$ and $66\frac{1}{3}°$, we may take 496.

For precision, take the difference between each two terms concerned, and with them enter Table XXIX. against 60 in the side column; the parts required will be found against the minutes in the side column. As M is always greater than N, they can never be confounded together.

*Ex.* Find M for 59° 47′ and 66° 18′

| | | |
|---|---|---|
| 59° and 66°, give | | M 477.4 |
| 59° and 60°, Diff. 14.3; this against 60 (p. 88) gives for | 47′ | 11.2 |
| 66° and 67°, Diff. 19.3; " " (p. 88) " | 18′ | 5.9 |
| | | M 494.5 |

This process will not always be correct, because M and N do not increase uniformly.

### Table XXII. *Table of Factors.*

This table contains the natural sines for every 15′ to 90°, and for every minute of time to $6^h$. Interpolation for minutes of arc or seconds of time is easy, and requires no explanation. The table is intended to be used with the Spherical Traverse Table, and its use is sufficiently explained in the various examples: the position of the decimal point is also fixed with reference to that table.

### Table XXIII. *Logarithms of Numbers.*

This is a table of common logarithms, to four places, rendered very convenient in use by the table of proportional parts annexed. To take out the log. corresponding to any number, enter with the first two figures at the side and the third at the top, and take from the column of prop. parts the number corresponding to the fourth figure, which add to the log. of the first three. The inverse process requires no explanation.

### Table XXIV. *The Moon's Second Correction of Distance.*

Enter the table with the app. dist. at the top or bottom, and the moon's corr. of alt. at the side, and take out the seconds.

In the same column take out the seconds standing against the corr. of dist. at the side. The difference between these two numbers thus taken out is the second corr. required.

When the dist. is *less* than 90°, *add;* when *greater* than 90°, *subtract.*

### Tables XXV., XXVI. *Correction for the Spheroidal Figure of the Earth.*

These tables, furnished by Prof. Chauvenet, U. S. N., contain the corr. of the moon's parallax, and a log. to be used in computing the corr. of the lunar dist., or the moon's polar dist., for the spheroidal figure of the earth. The log. is to be taken out with the hor. par. at the top, and the lat. at the side. The corr. Table XXV. is always to be *added* to the hor. par. to obtain the corrected hor. par.

### Table XXVII. *Logarithmic Sines to Ten Seconds.*

This table contains the log. sines of the first 5° of the quadrant to each 10″, and the sixth degree to each 20″ and the half minute, to five places. They are also the cosines of the last six degrees.

To find the log. sine of an arc to a number of seconds not exactly 10:—Take the diff. between the sines of the next greater and next less arcs in the table; multiply this diff. by the number of single seconds above 10; cut off one cipher to the right, and *add* the product to the log. sine first taken out.

*Ex.* Find the log. sine of 3° 14′ 37″.

| | | |
|---|---|---|
| 3° 14′ 30″ | 8.75241 | Then 38×7=266; hence, 26.6 or 27 added to 8.75241 gives the |
| 40 | 8.75279 | |
| Diff. | 38 | Log. sine required 8.75268 |

To take out the log. cosine, proceed as above but *subtract* the product.

To take out the arc corresponding to a given log. sine or cosine to single seconds.—For the sine: look for the next *less,* and note the deg. min. and 10″. For the cosine: look for the next *greater;* note the deg. min. and 10″. Write down the given log. the next less and the next greater in the order in which the arc is read. Take the diff. between the first and second, and the second and third.

Annex one cipher to the less of the two differences and divide it by the greater; the quotient is the number of seconds to be added to the 10″.

*Ex.* 1. Find the arc to the log. sine 8.75268.

| | | |
|---|---|---|
| Given | 8.75268 | |
| Next less | 8.75241 | 27 |
| Next greater | 8.75279 | 38 |

Then 270 divided by 38 gives 7, which added to 3° 14′ 40″, the arc answering to 8.75241, gives the arc required 3° 14′ 37″.

*Ex.* 2. Find the arc to the log. cosine 8.75268.

| | | |
|---|---|---|
| Given | 8.75268 | |
| Next greater | 8.75279 | 11 |
| Next less | 8.75241 | 38 |

Then 110 divided by 38 gives 3, which added to 86° 45′ 20″, the arc answering to 8.75279, gives the arc required 86° 45′ 23″.

In working to four places the arc corresponding is readily taken out by inspection.

It is also intended to substitute this table for the prop. logs. usually given to reduce the lunar distance to the interval.

Degrees are to be taken as hours, minutes (′) as minutes (ᵐ) of time, and seconds (″) as seconds (ˢ) of time. This is theoretically inaccurate, inasmuch as it assumes that the arc is equal to its sine—in practice, to four places of decimals, it is as accurate as the method by prop. logs.

### Table XXVIII. *Logarithmic Sines, Cosines, &c.*

This table contains these quantities for each minute of arc, or $4^s$ of time, to six places.

The second column, and the last but one, contain a time scale. The minutes of time are denoted by large figures, and the seconds by small figures; the hour with certain minutes being taken from the top or bottom. This scale is convenient for turning degrees into time, and the converse, (as in Bowditch's Table XXI.) Thus, 73° 33′ correspond to $4^h\ 54^m\ 12^s$.

The column headed D. contains the difference for 100″.

*To find the Log. Sine, &c. to Degrees, Minutes, and Seconds.*—When the given angle is less than 45°, or greater than 135°, its log. sine, &c. are taken from the top; when greater than 45° and less than 135°, from the bottom. When the degrees are taken from the top, the names of sine, secant, &c. are to be taken from the top.

Take out the quantity for the given degree and minute, and note the D. Enter Table XXIX. with this D. at the top, and the given second at the side, and take out the parts. For the sine, tangent, and secant, *add* these parts; for the *co*-sine, *co*-tangent, and *co*-secant, *subtract* them.

*Ex.* 1. Find the log. tan. of 53° 25′ 33″.

| | | |
|---|---|---|
| 53° 25′ log. tan. | 0.129471 | D. 440 |
| D. 440 and 33″ | +145 | |
| Log. tan. required | 0.129616 | |

*Ex.* 2. Find the log. co-secant of 8° 29′ 56″

| | | | |
|---|---|---|---|
| 8° 29′ log. cosec. | | 0.831144 | D. 1410 |
| D. 1000 and 56″ | 560 | | |
| 400 | 224 | −790 | |
| 10 | 6 | | |
| Log. cosec. required | | 0.830354 | |

Or, multiply the D. by the number of seconds, cut off the last two figures, and add the remainder.

*To find the Arc to Seconds, corresponding to a given Log. Sine, &c.*—For the sine, tangent, or secant, take out the next *less* in the table; for the *co*-sine, *co*-tangent, or *co*-secant, take out the next *greater*. Note the degree and minute of the quantity taken out. Take the diff. between this quantity and the given one; then with the D. for 100″ at the top, enter Table XXIX. and find in the same column the diff. deduced; take out the seconds, and add them.

*Ex.* 1. Find the arc to the log. tan. 0.129616.

| | | | |
|---|---|---|---|
| Given | - - | 0.129616 | |
| Next less | 53° 25′ | 0.129471 | D. 440 |
| | Diff. | 145 | |

In Table XXIX. D. 440 and 145 give 33″. Arc required 53° 25′ 33″.

*Ex.* 2. Find the arc to the log. cosec. 0.830354.

| | | | |
|---|---|---|---|
| Given | - - | 0.830354 | |
| Next greater | 8° 29′ | 0.831144 | D. 1410 |
| | Diff. | 790 | |

Diff. 1410 and 790, or nearly enough 141 and 79, give 56″. Arc required 8° 29′ 56″.

Or, annex two ciphers to the diff. and divide by the D.; the quotient will be the number of seconds to be added.

*In working to Seconds of Time*, take the diff. of the two sines, &c. between which the required one falls, and divide it by 2, 3, or 4. No example is required.

In using the D. for 100″, when working to less than six figures, as many figures must be dropped in the D. as are dropped in the logs.

### Table XXIX. *For Interpolation.*

This is a general proportional table, but its principal use being in connection with Table XXVIII. it follows it.

The table is entered with the diff. for 100 at the top, and the unit or seconds at the side. Thus under the D. 620, the parts corresponding to 37″ are 229.

The table may be employed for other numbers than 100 and 60, as will appear from the following example:—

***Ex.*** The daily variation of a quantity is 156, required the proportional part for 17 hours. 156 against 24 in the side column is midway between the numbers 154 and 158 in the columns headed 640 and 660, the number answering to 17 is therefore midway between 109 and 112, or about 110½.

The general use of this table has been explained in the examples to Tables XXI. and XXVIII. The manner of using it where several logs. occur together is shown in Ex. 1. p. 33.

**TABLE I.—Correction to be *added* to the Observed Altitude of the Sun's Lower Limb, to find the True Altitude.**

| Obs. Alt. | Height of the Eye above the Sea in Feet. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| ° | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| 5 | 3 8 | 3·5 | 3·1 | 2 8 | 2·5 | 2·3 | 2·1 | 1·8 | 1·6 | 1·4 | 1·2 | 1·0 | 0 8 |
| 6 | 5 3 | 4 9 | 4·6 | 4 3 | 4 0 | 3·7 | 3 5 | 3 3 | 3 0 | 2 8 | 2 6 | 2·4 | 2·2 |
| 7 | 6 4 | 6 0 | 5 7 | 5 4 | 5 1 | 4 8 | 4 6 | 4 4 | 4 1 | 3·9 | 3 7 | 3 5 | 3 3 |
| 8 | 7·2 | 6 8 | 6 5 | 6 2 | 5 9 | 5 7 | 5 4 | 5 3 | 5 0 | 4 8 | 4 6 | 4 4 | 4·2 |
| 9 | 7 9 | 7 5 | 7·2 | 6 9 | 6·6 | 6 4 | 6 1 | 5 9 | 5 7 | 5 5 | 5 3 | 5 1 | 4 9 |
| 10 | 8 5 | 8·1 | 7 8 | 7 5 | 7·2 | 6·9 | 6 7 | 6 5 | 6·2 | 6 0 | 5 8 | 5 6 | 5 4 |
| 11 | 8 9 | 8 6 | 8 2 | 7 9 | 7 6 | 7 4 | 7·2 | 6 9 | 6 7 | 6 5 | 6 3 | 6 1 | 5 9 |
| 12 | 9·3 | 9 0 | 8 7 | 8 3 | 8·0 | 7 8 | 7 6 | 7 3 | 7 1 | 6 9 | 6 7 | 6 5 | 6 3 |
| 14 | 9 9 | 9 6 | 9 2 | 8·9 | 8 7 | 8 4 | 8 2 | 7 9 | 7 7 | 7 5 | 7 3 | 7 1 | 6 9 |
| 16 | 10 4 | 10 1 | 9 7 | 9 4 | 9 1 | 8 9 | 8 7 | 8 4 | 8·2 | 8 0 | 7 8 | 7 6 | 7 4 |
| 18 | 10 8 | 10 4 | 10 1 | 9 8 | 9 5 | 9 3 | 9 0 | 8 8 | 8·6 | 8 4 | 8 2 | 8 0 | 7 8 |
| 20 | 11 1 | 10 7 | 10 4 | 10 1 | 9 8 | 9 6 | 9·3 | 9 1 | 8 9 | 8 7 | 8 5 | 8 2 | 8·1 |
| 22 | 11 4 | 11·0 | 10 7 | 10 4 | 10 1 | 9 8 | 9 6 | 9 4 | 9 1 | 8 9 | 8 7 | 8 5 | 8·3 |
| 26 | 11 7 | 11·4 | 11 0 | 10 7 | 10 5 | 10 2 | 10 0 | 9 7 | 9 5 | 9 3 | 9·1 | 8 9 | 8·7 |
| 30 | 12 0 | 11·7 | 11 3 | 11 0 | 10 8 | 10 5 | 10 3 | 10 0 | 9 8 | 9 6 | 9 4 | 9·2 | 9 0 |
| 35 | 12 3 | 11 9 | 11 6 | 11 3 | 11 0 | 10 7 | 10·6 | 10 3 | 10 1 | 9 9 | 9 7 | 9 4 | 9 2 |
| 40 | 12 5 | 12 2 | 11 8 | 11 5 | 11·3 | 11 0 | 10 8 | 10 5 | 10 3 | 10 1 | 9 9 | 9 7 | 9 5 |
| 45 | 12 7 | 12 4 | 12 0 | 11 7 | 11 5 | 11 2 | 11 0 | 10 7 | 10 5 | 10 2 | 10 1 | 9 8 | 9·7 |
| 50 | 12 8 | 12 5 | 12 2 | 11 9 | 11 6 | 11 3 | 11 1 | 10 9 | 10 6 | 10 4 | 10 3 | 10 0 | 9 8 |
| 55 | 13 0 | 12 6 | 12 3 | 12 0 | 11·7 | 11 5 | 11 2 | 11 0 | 10 7 | 10 5 | 10 3 | 10 1 | 9 9 |
| 60 | 13 1 | 12 7 | 12 4 | 12 1 | 11 8 | 11·6 | 11 3 | 11 1 | 10 9 | 10 6 | 10 4 | 10 2 | 10 1 |
| 65 | 13 2 | 12 8 | 12 5 | 12 2 | 11 9 | 11 7 | 11 4 | 11 2 | 11 0 | 10 7 | 10 5 | 10 3 | 10·1 |
| 70 | 13 3 | 12 9 | 12 6 | 12 3 | 12 0 | 11 8 | 11 5 | 11 3 | 11 0 | 10 8 | 10 6 | 10 4 | 10 2 |
| 80 | 13 4 | 13 1 | 12 7 | 12 4 | 12·1 | 11 9 | 11 7 | 11 4 | 11 2 | 11 0 | 10 8 | 10 6 | 10 4 |
| 90 | 13 6 | 13 2 | 12 9 | 12 6 | 12 3 | 12 0 | 11 8 | 11 6 | 11 3 | 11·1 | 10 9 | 10 7 | 10 5 |

| Month, | Jan. | Feb. | Mar. | April, | May, | June, |
|---|---|---|---|---|---|---|
| Correction, | + 0′·3 | + 0′·2 | + 0′·1 | 0′·0 | — 0′·1 | — 0′·2 |

| Month, | July, | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|
| Correction, | — 0′·3 | — 0′·2 | — 0′·1 | + 0′·1 | + 0′·2 | + 0′·3 |

**TABLE II.—Correction to be *subtracted* from the Observed Altitude of a Fixed Star, to find the true Altitude.**

| Obs. Alt. | Height of the Eye above the Sea in Feet. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| ° | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| 5 | 12 3 | 12·7 | 13 0 | 13·3 | 13 6 | 13·8 | 14 1 | 14·3 | 14 6 | 14 8 | 15·0 | 15·2 | 15·3 |
| 6 | 10 9 | 11·3 | 11 6 | 11·9 | 12·2 | 12 4 | 12 7 | 12 9 | 13 2 | 13 4 | 13 6 | 13 8 | 13 9 |
| 7 | 9 8 | 10·2 | 10 5 | 10 8 | 11·1 | 11 3 | 11 6 | 11 8 | 12·1 | 12 3 | 12 5 | 12 7 | 12 8 |
| 8 | 8 9 | 9·3 | 9 6 | 9 9 | 10 2 | 10 4 | 10 7 | 10·9 | 11·2 | 11·4 | 11 6 | 11 8 | 11·9 |
| 9 | 8 2 | 8 6 | 8 9 | 9 2 | 9 5 | 9 7 | 10 0 | 10 2 | 10 5 | 10 7 | 10 9 | 11·1 | 11·2 |
| 10 | 7 7 | 8·1 | 8 4 | 8 7 | 9 0 | 9 2 | 9 5 | 9 7 | 10 0 | 10 2 | 10 4 | 10 6 | 10 7 |
| 11 | 7·2 | 7 6 | 7 9 | 8·2 | 8 5 | 8·7 | 9 0 | 9 2 | 9 5 | 9 7 | 9 9 | 10 1 | 10·2 |
| 12 | 6 8 | 7·2 | 7 5 | 7 8 | 8 1 | 8 3 | 8 6 | 8 8 | 9 1 | 9 3 | 9 5 | 9 7 | 9 8 |
| 14 | 6 2 | 6 6 | 6 9 | 7 2 | 7 5 | 7 7 | 8 0 | 8·2 | 8 5 | 8 7 | 8 9 | 9 1 | 9·2 |
| 16 | 5 7 | 6 1 | 6 4 | 6 7 | 7 0 | 7 2 | 7 5 | 7 7 | 8 0 | 8 2 | 8 4 | 8 6 | 8·7 |
| 18 | 5 3 | 5 7 | 6 0 | 6 3 | 6 6 | 6 8 | 7·1 | 7·3 | 7 6 | 7 8 | 8 0 | 8 2 | 8·3 |
| 20 | 5·0 | 5·4 | 5 7 | 6 0 | 6 3 | 6 5 | 6 8 | 7·0 | 7·3 | 7 5 | 7 7 | 7 9 | 8·0 |
| 22 | 4 8 | 5·2 | 5 5 | 5 8 | 6 1 | 6 3 | 6 6 | 6 8 | 7·1 | 7·3 | 7 5 | 7 7 | 7·8 |
| 25 | 4 4 | 4 8 | 5 1 | 5·4 | 5 7 | 5 9 | 6 2 | 6 4 | 6 7 | 6 9 | 7 1 | 7 3 | 7·4 |
| 30 | 4 1 | 4 5 | 4 8 | 5 1 | 5 4 | 5 6 | 5 9 | 6 1 | 6 4 | 6 6 | 6 8 | 7 0 | 7·1 |
| 35 | 3 8 | 4·2 | 4 5 | 4 8 | 5 1 | 5 3 | 5 6 | 5 8 | 6 1 | 6 3 | 6 5 | 6 7 | 6 8 |
| 40 | 3 6 | 4·0 | 4 3 | 4 6 | 4 9 | 5 1 | 5 4 | 5 6 | 5 9 | 6 1 | 6 3 | 6 5 | 6 6 |
| 45 | 3 4 | 3 8 | 4·1 | 4 4 | 4 7 | 4 9 | 5·2 | 5·4 | 5 7 | 5 9 | 6 1 | 6 3 | 6 5 |
| 50 | 3·2 | 3 6 | 3 9 | 4 2 | 4 5 | 4 7 | 5 0 | 5·2 | 5 5 | 5 7 | 5 9 | 6 1 | 6 3 |
| 55 | 3·1 | 3 5 | 3 8 | 4 1 | 4 4 | 4 6 | 4 9 | 5·1 | 5 4 | 5 6 | 5 8 | 6 0 | 6·2 |
| 60 | 3 0 | 3 4 | 3 7 | 4 0 | 4 3 | 4 5 | 4 8 | 5·0 | 5 3 | 5 5 | 5 7 | 5 9 | 6·1 |
| 65 | 2·9 | 3·3 | 3 6 | 3 9 | 4·2 | 4 4 | 4 7 | 4 9 | 5 2 | 5 4 | 5 6 | 5 8 | 6 0 |
| 70 | 2·8 | 3·2 | 3 5 | 3 8 | 4·1 | 4·3 | 4 6 | 4·8 | 5 1 | 5 3 | 5 5 | 5 7 | 5 9 |
| 80 | 2·6 | 3·0 | 3 3 | 3 7 | 3·9 | 4·1 | 4 4 | 4 6 | 4·9 | 5·1 | 5·3 | 5 5 | 5·7 |
| 90 | 2·4 | 2·8 | 3·1 | 3·4 | 3·7 | 3 9 | 4·2 | 4 4 | 4 7 | 4 9 | 5·1 | 5·3 | 5·5 |

**TABLE III. Sun's Semidiameter.**

| Month. | Days. | Sun's Semidiam. |
|---|---|---|
| | | ′ ″ |
| January. | 1 | 16 17 |
| | 7 | 16 17 |
| | 13 | 16 17 |
| | 19 | 16 17 |
| | 25 | 16 16 |
| February. | 1 | 16 15 |
| | 7 | 16 14 |
| | 13 | 16 13 |
| | 19 | 16 12 |
| | 25 | 16 10 |
| March. | 1 | 16 9 |
| | 7 | 16 8 |
| | 13 | 16 6 |
| | 19 | 16 4 |
| | 25 | 16 3 |
| April. | 1 | 16 1 |
| | 7 | 15 59 |
| | 13 | 15 58 |
| | 19 | 15 56 |
| | 25 | 15 54 |
| May. | 1 | 15 53 |
| | 7 | 15 52 |
| | 13 | 15 50 |
| | 19 | 15 49 |
| | 25 | 15 48 |
| June. | 1 | 15 47 |
| | 7 | 15 46 |
| | 13 | 15 46 |
| | 19 | 15 45 |
| | 25 | 15 45 |
| July. | 1 | 15 45 |
| | 7 | 15 45 |
| | 13 | 15 45 |
| | 19 | 15 46 |
| | 25 | 15 46 |
| August. | 1 | 15 47 |
| | 7 | 15 48 |
| | 13 | 15 49 |
| | 19 | 15 50 |
| | 25 | 15 51 |
| September. | 1 | 15 53 |
| | 7 | 15 54 |
| | 13 | 15 56 |
| | 19 | 15 57 |
| | 25 | 15 59 |
| October. | 1 | 16 1 |
| | 7 | 16 2 |
| | 13 | 16 4 |
| | 19 | 16 6 |
| | 25 | 16 7 |
| November. | 1 | 16 9 |
| | 7 | 16 11 |
| | 13 | 16 12 |
| | 19 | 16 13 |
| | 25 | 16 14 |
| December. | 1 | 16 15 |
| | 7 | 16 16 |
| | 13 | 16 16 |
| | 19 | 16 17 |
| | 25 | 16 17 |

## TABLE IV.

| APPARENT DIP OF THE SEA HORIZON. | |
|---|---|
| Ht. | Dip. |
| 0 | 0′ 0″ |
| 1 | 1 0 |
| 2 | 1 20 |
| 3 | 1 40 |
| 4 | 2 0 |
| 5 | 2 10 |
| 6 | 2 20 |
| 7 | 2 40 |
| 8 | 2 50 |
| 9 | 3 0 |
| 10 | 3 10 |
| 12 | 3 20 |
| 14 | 3 40 |
| 16 | 4 0 |
| 18 | 4 10 |
| 20 | 4 20 |
| 22 | 4 30 |
| 24 | 4 50 |
| 26 | 5 0 |
| 28 | 5 10 |
| 30 | 5 20 |
| 35 | 5 50 |
| 40 | 6 10 |
| 45 | 6 50 |
| 50 | 7 0 |
| 55 | 7 20 |
| 60 | 7 40 |
| 65 | 8 0 |
| 70 | 8 10 |
| 75 | 8 30 |
| 80 | 8 50 |
| 85 | 9 0 |
| 90 | 9 20 |
| 100 | 9 50 |

## TABLE V.

### MEAN ASTRONOMICAL REFRACTION.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| App. Alt. | Refrac. | D. to 10′ | App. Alt. | Refrac. | D. to 10′ | App. Alt. | Refrac. | D. to 10′ | App. Alt. | Refrac. | D. to 10′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0° 0′ | 34′ 17″ | 122″ | 6°10′ | 8′ 18″ | 12″ | 12°50′ | 4′ 11″ | 3″.2 | 35° 0′ | 1′ 23·2 | ″.50 |
| 10 | 32 15 | 112 | 15 | 8 12 | 12 | 13 0 | 4 8 | 3·1 | 30 | 1 21·7 | ·50 |
| 20 | 30 23 | 102 | 20 | 8 6 | 11 | 10 | 4 5 | 3·1 | 36 0 | 1 20·2 | ·47 |
| 30 | 28 41 | 94 | 25 | 8 1 | 11 | 20 | 4 2 | 3·0 | 30 | 1 18·8 | ·47 |
| 40 | 27 7 | 86 | 30 | 7 56 | 11 | 30 | 3 59 | 3·0 | 37 0 | 1 17·4 | ·47 |
| 50 | 25 41 | 78 | 35 | 7 50 | 11 | 40 | 3 56 | 2·9 | 30 | 1 16·0 | ·47 |
| 1 0 | 24 22 | 73 | 40 | 7 45 | 10 | 50 | 3 53 | 2·9 | 38 0 | 1 14·6 | ·43 |
| 10 | 23 9 | 67 | 45 | 7 40 | 10 | 14 0 | 3 50 | 2·8 | 30 | 1 13·3 | ·43 |
| 20 | 22 2 | 62 | 50 | 7 35 | 10 | 10 | 3 47 | 2·7 | 39 0 | 1 12·0 | ·43 |
| 30 | 21 0 | 58 | 55 | 7 30 | 10 | 20 | 3 45 | 2·6 | 30 | 1 10·7 | ·42 |
| 40 | 20 2 | 53 | 7 0 | 7 25 | 9 | 30 | 3 42 | 2·5 | 40 0 | 1 9·5 | ·40 |
| 50 | 19 9 | 49 | 5 | 7 20 | 9 | 40 | 3 40 | 2·5 | 41 0 | 1 7·1 | ·38 |
| 2 0 | 18 20 | 46 | 10 | 7 16 | 9 | 50 | 3 37 | 2·4 | 42 0 | 1 4·8 | ·35 |
| 10 | 17 34 | 44 | 15 | 7 11 | 9 | 15 0 | 3 35 | 2·4 | 43 0 | 1 2·6 | ·34 |
| 15 | 17 12 | 42 | 20 | 7 7 | 9 | 10 | 3 32 | 2·3 | 44 0 | 1 0·4 | ·34 |
| 20 | 16 51 | 40 | 25 | 7 3 | 9 | 20 | 3 30 | 2·2 | 45 0 | 0 58·4 | ·33 |
| 25 | 16 31 | 39 | 30 | 6 59 | 9 | 30 | 3 28 | 2·2 | 46 0 | 0 56·3 | ·32 |
| 30 | 16 11 | 38 | 35 | 6 54 | 9 | 40 | 3 25 | 2·1 | 47 0 | 0 54·4 | ·31 |
| 35 | 15 52 | 37 | 40 | 6 50 | 8 | 50 | 3 23 | 2·1 | 48 0 | 0 52·6 | ·30 |
| 40 | 15 34 | 36 | 45 | 6 46 | 8 | 16 0 | 3 21 | 2·1 | 49 0 | 0 50·7 | ·29 |
| 45 | 15 16 | 35 | 50 | 6 42 | 8 | 10 | 3 19 | 2·1 | 50 0 | 0 49·0 | ·28 |
| 50 | 14 59 | 34 | 55 | 6 38 | 8 | 20 | 3 17 | 2·1 | 51 0 | 0 47·3 | ·27 |
| 55 | 14 42 | 33 | 8 0 | 6 35 | 8 | 30 | 3 15 | 2·1 | 52 0 | 0 45·6 | ·26 |
| 3 0 | 14 26 | 32 | 5 | 6 31 | 7 | 40 | 3 13 | 2·0 | 53 0 | 0 44·0 | ·26 |
| 5 | 14 10 | 31 | 10 | 6 27 | 7 | 50 | 3 11 | 2·0 | 54 0 | 0 42·4 | ·25 |
| 10 | 13 55 | 30 | 15 | 6 23 | 7 | 17 0 | 3 9 | 2·0 | 55 0 | 0 40·9 | ·25 |
| 15 | 13 41 | 29 | 20 | 6 20 | 7 | 30 | 3 3 | 1·9 | 56 0 | 0 39·4 | ·25 |
| 20 | 13 27 | 28 | 25 | 6 16 | 7 | 18 0 | 2 58 | 1·9 | 57 0 | 0 37·9 | ·24 |
| 25 | 13 13 | 27 | 30 | 6 13 | 7 | 30 | 2 53 | 1·8 | 58 0 | 0 36·5 | ·24 |
| 30 | 13 0 | 26 | 35 | 6 9 | 7 | 19 0 | 2 48 | 1·7 | 59 0 | 0 35·1 | ·23 |
| 35 | 12 47 | 25 | 40 | 6 6 | 7 | 30 | 2 44 | 1·6 | 60 0 | 0 33·7 | ·22 |
| 40 | 12 34 | 25 | 45 | 6 3 | 6 | 20 0 | 2 39 | 1·5 | 61 0 | 0 32·4 | ·22 |
| 45 | 12 22 | 24 | 50 | 6 0 | 6 | 30 | 2 35 | 1·4 | 62 0 | 0 31·0 | ·22 |
| 50 | 12 10 | 24 | 55 | 5 57 | 6 | 21 0 | 2 31 | 1·3 | 63 0 | 0 29·8 | ·21 |
| 55 | 11 58 | 23 | 9 0 | 5 54 | 6 | 30 | 2 27 | 1·2 | 64 0 | 0 28·5 | ·21 |
| 4 0 | 11 47 | 22 | 5 | 5 51 | 6 | 22 0 | 2 24 | 1·2 | 65 0 | 0 27·2 | ·20 |
| 5 | 11 36 | 21 | 10 | 5 48 | 6 | 30 | 2 20 | 1·1 | 66 0 | 0 26·0 | ·20 |
| 10 | 11 26 | 21 | 15 | 5 45 | 6 | 23 0 | 2 17 | 1·1 | 67 0 | 0 24·8 | ·20 |
| 15 | 11 15 | 20 | 20 | 5 42 | 6 | 30 | 2 13 | 1·0 | 68 0 | 0 23·6 | ·20 |
| 20 | 11 5 | 20 | 25 | 5 39 | 6 | 24 0 | 2 10 | 1·0 | 69 0 | 0 22·4 | ·20 |
| 25 | 10 55 | 19 | 30 | 5 36 | 5 | 30 | 2 7 | 0·9 | 70 0 | 0 21·3 | ·20 |
| 30 | 10 46 | 19 | 35 | 5 33 | 5 | 25 0 | 2 5 | 0·9 | 71 0 | 0 20·1 | ·20 |
| 35 | 10 37 | 18 | 40 | 5 31 | 5 | 30 | 2 2 | 0·9 | 72 0 | 0 19·0 | ·19 |
| 40 | 10 28 | 18 | 50 | 5 25 | 5 | 26 0 | 1 59 | 0·9 | 73 0 | 0 17·9 | ·19 |
| 45 | 10 19 | 18 | 10 0 | 5 20 | 5 | 30 | 1 56 | 0·9 | 74 0 | 0 16·7 | ·18 |
| 50 | 10 10 | 17 | 10 | 5 15 | 5 | 27 0 | 1 54 | 0·8 | 75 0 | 0 15·7 | ·18 |
| 55 | 10 2 | 16 | 20 | 5 10 | 5 | 30 | 1 51 | 0·8 | 76 0 | 0 14·6 | ·18 |
| 5 0 | 9 54 | 16 | 30 | 5 6 | 5 | 28 0 | 1 49 | 0·8 | 77 0 | 0 13·5 | ·17 |
| 5 | 9 46 | 16 | 40 | 5 1 | 5 | 30 | 1 47 | 0·7 | 78 0 | 0 12·4 | ·17 |
| 10 | 9 38 | 15 | 50 | 4 56 | 4 | 29 0 | 1 45 | 0·7 | 79 0 | 0 11·3 | ·17 |
| 15 | 9 30 | 15 | 11 0 | 4 52 | 4 | 30 | 1 43 | 0·7 | 80 0 | 0 10·3 | ·17 |
| 20 | 9 23 | 15 | 10 | 4 48 | 4 | 30 0 | 1 41 | 0·7 | 81 0 | 0 9·2 | ·17 |
| 25 | 9 16 | 15 | 20 | 4 44 | 4 | 30 | 1 39 | 0·7 | 82 0 | 0 8·2 | ·17 |
| 30 | 9 9 | 14 | 30 | 4 40 | 4 | 31 0 | 1 37 | 0·6 | 83 0 | 0 7·2 | ·17 |
| 35 | 9 2 | 14 | 40 | 4 36 | 4 | 30 | 1 35 | 0·6 | 84 0 | 0 6·1 | ·17 |
| 40 | 8 55 | 14 | 50 | 4 32 | 4 | 32 0 | 1 33 | 0·6 | 85 0 | 0 5·1 | ·17 |
| 45 | 8 48 | 13 | 12 0 | 4 28 | 4 | 30 | 1 31 | 0·6 | 86 0 | 0 4·1 | ·17 |
| 50 | 8 42 | 13 | 10 | 4 25 | 4 | 33 0 | 1 30 | 0·6 | 87 0 | 0 3·1 | ·17 |
| 55 | 8 36 | 13 | 20 | 4 21 | 4 | 30 | 1 28 | 0·5 | 88 0 | 0 2·0 | ·17 |
| 6 0 | 8 30 | 12 | 30 | 4 18 | 4 | 34 0 | 1 26 | 0·5 | 89 0 | 0 1·0 | ·17 |
| 5 | 8 24 | 12 | 40 | 4 14 | 4 | 30 | 1 25 | 0·5 | 90 0 | 0 0 | ·17 |

## CORRECTION OF THE MEAN REFRACTION FOR THE HEIGHT OF THE THERMOMETER.

| Therm. *add.* | ALTITUDES. | | | | | | | | | | | | | | | | | Therm. *sub.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4° | 5° | 5½° | 6° | 6½° | 7° | 7½° | 8° | 9° | 10° | 12° | 15° | 20° | 30° | 40° | 50° | 70° | 90° | |
| 0° | 69″ | 61″ | 57″ | 54″ | 51″ | 48″ | 46″ | 43″ | 39″ | 36″ | 30″ | 25″ | 18″ | 12″ | 8″1 | 5″7 | 2″5 | 0″ | |
| 2 | 66 | 58 | 55 | 51 | 48 | 46 | 43 | 41 | 37 | 34 | 29 | 23 | 18 | 11 | 7·7 | 5·4 | 2·4 | 0 | |
| 4 | 63 | 56 | 52 | 49 | 46 | 44 | 41 | 39 | 36 | 32 | 28 | 22 | 17 | 11 | 7·4 | 5·2 | 2·3 | 0 | |
| 6 | 60 | 53 | 50 | 47 | 44 | 42 | 39 | 37 | 34 | 31 | 26 | 21 | 16 | 10 | 7·0 | 4·9 | 2·1 | 0 | |
| 8 | 57 | 50 | 47 | 44 | 42 | 40 | 37 | 36 | 32 | 29 | 25 | 20 | 15 | 10 | 6·7 | 4·7 | 2·0 | 0 | |
| 10 | 55 | 48 | 45 | 42 | 40 | 37 | 35 | 34 | 31 | 28 | 24 | 19 | 14 | 9 | 6·3 | 4·4 | 1·9 | 0 | 100° |
| 12 | 51 | 45 | 42 | 40 | 37 | 35 | 34 | 32 | 29 | 26 | 22 | 18 | 14 | 9 | 6·0 | 4·2 | 1·8 | 0 | 96 |
| 14 | 48 | 42 | 40 | 37 | 35 | 33 | 32 | 30 | 27 | 25 | 21 | 17 | 13 | 8 | 5·6 | 4·0 | 1·7 | 0 | 93 |
| 16 | 44 | 40 | 37 | 35 | 33 | 31 | 30 | 28 | 26 | 23 | 20 | 16 | 12 | 8 | 5·3 | 3 7 | 1·6 | 0 | 90 |
| 18 | 42 | 37 | 35 | 33 | 31 | 29 | 28 | 26 | 24 | 22 | 19 | 15 | 11 | 7 | 5·0 | 3 5 | 1·5 | 0 | 87 |
| 20 | 39 | 35 | 33 | 31 | 29 | 28 | 26 | 25 | 22 | 20 | 17 | 14 | 11 | 7 | 4 6 | 3 3 | 1·4 | 0 | 85 |
| 22 | 36 | 32 | 30 | 29 | 27 | 25 | 24 | 23 | 21 | 19 | 16 | 13 | 10 | 6 | 4·3 | 3·0 | 1·3 | 0 | 82 |
| 24 | 33 | 30 | 27 | 26 | 25 | 24 | 22 | 21 | 19 | 17 | 15 | 12 | 9 | 6 | 4·0 | 2·8 | 1·2 | 0 | 79 |
| 26 | 30 | 27 | 26 | 24 | 23 | 22 | 20 | 19 | 18 | 16 | 14 | 11 | 8 | 5 | 3·7 | 2·6 | 1·1 | 0 | 77 |
| 28 | 28 | 25 | 23 | 22 | 21 | 20 | 19 | 18 | 16 | 15 | 12 | 10 | 8 | 5 | 3 3 | 2·4 | 1·0 | 0 | 74 |
| 30 | 26 | 23 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 13 | 11 | 9 | 7 | 4 | 3·0 | 2·1 | 0·9 | 0 | 72 |
| 32 | 22 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 10 | 8 | 6 | 4 | 2·7 | 1·9 | 0·8 | 0 | 70 |
| 34 | 21 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 10 | 9 | 7 | 5 | 3 | 2·4 | 1·7 | 0·7 | 0 | 68 |
| 36 | 18 | 16 | 15 | 14 | 13 | 12 | 12 | 11 | 10 | 9 | 8 | 6 | 5 | 3 | 2·1 | 1·5 | 0·6 | 0 | 65 |
| 38 | 15 | 13 | 12 | 12 | 11 | 10 | 10 | 9 | 9 | 8 | 7 | 5 | 4 | 3 | 1·8 | 1·3 | 0·5 | 0 | 63 |
| 40 | 13 | 11 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1·7 | 1·0 | 0·4 | 0 | 61 |
| 42 | 10 | 9 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 5 | 4 | 3 | 3 | 2 | 1·2 | 0·8 | 0·4 | 0 | 58 |
| 44 | 7 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 4 | 3 | 3 | 2 | 1 | 0·9 | 0·6 | 0·3 | 0 | 56 |
| 46 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 0·6 | 0·4 | 0·2 | 0 | 54 |
| 48 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0·3 | 0·2 | 0·1 | 0 | 52 |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |

## CORRECTION OF THE MEAN REFRACTION FOR THE HEIGHT OF THE BAROMETER.

| Bar. *sub.* | ALTITUDES. | | | | | | | | | | | | | | | | | Bar. *add.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4° | 5° | 5½° | 6° | 6½° | 7° | 7½° | 8° | 9° | 10° | 12° | 15° | 20° | 30° | 40° | 50° | 70° | 90° | |
| 27·5 | 60″ | 50″ | 46″ | 42″ | 40″ | 37″ | 35″ | 33″ | 29″ | 27″ | 22″ | 18″ | 13″ | 8″ | 5″8 | 4″0 | 1″8 | 0″ | |
| 27·6 | 57 | 48 | 44 | 41 | 38 | 36 | 34 | 32 | 28 | 26 | 21 | 17 | 13 | 8 | 5·5 | 3·8 | 1·7 | 0 | |
| 27·7 | 54 | 46 | 42 | 39 | 37 | 34 | 32 | 30 | 27 | 25 | 20 | 17 | 12 | 8 | 5·3 | 3·7 | 1·6 | 0 | |
| 27·8 | 51 | 44 | 40 | 37 | 35 | 33 | 31 | 29 | 26 | 24 | 20 | 16 | 12 | 7 | 5·1 | 3·5 | 1·5 | 0 | |
| 27·9 | 48 | 42 | 38 | 36 | 33 | 31 | 29 | 28 | 25 | 22 | 19 | 15 | 11 | 7 | 4·8 | 3·3 | 1·5 | 0 | |
| 28·0 | 46 | 40 | 37 | 34 | 32 | 30 | 28 | 26 | 24 | 21 | 18 | 14 | 11 | 7 | 4·6 | 3·2 | 1·4 | 0 | |
| 28·1 | 44 | 38 | 35 | 32 | 30 | 28 | 27 | 25 | 22 | 20 | 18 | 14 | 10 | 6 | 4·4 | 3·0 | 1·3 | 0 | |
| 28·2 | 41 | 36 | 33 | 31 | 29 | 27 | 25 | 24 | 21 | 19 | 17 | 13 | 10 | 6 | 4·1 | 2·9 | 1·3 | 0 | |
| 28·3 | 39 | 34 | 31 | 29 | 27 | 25 | 24 | 22 | 20 | 18 | 16 | 12 | 9 | 6 | 3·9 | 2·7 | 1·2 | 0 | |
| 28·4 | 37 | 32 | 29 | 27 | 25 | 24 | 22 | 21 | 19 | 17 | 15 | 12 | 8 | 5 | 3·7 | 2·6 | 1·1 | 0 | |
| 28·5 | 35 | 30 | 27 | 25 | 24 | 22 | 21 | 20 | 18 | 16 | 14 | 11 | 8 | 5 | 3·4 | 2·4 | 1·0 | 0 | 31·5 |
| 28·6 | 32 | 28 | 26 | 24 | 22 | 21 | 20 | 18 | 17 | 15 | 13 | 10 | 7 | 5 | 3·2 | 2·2 | 1·0 | 0 | 31·4 |
| 28·7 | 30 | 26 | 24 | 22 | 21 | 19 | 18 | 17 | 15 | 14 | 12 | 9 | 7 | 4 | 3·0 | 1·9 | 0·9 | 0 | 31·3 |
| 28·8 | 27 | 24 | 22 | 20 | 19 | 18 | 17 | 16 | 14 | 13 | 11 | 9 | 6 | 4 | 2·8 | 1·8 | 0·8 | 0 | 31·2 |
| 28·9 | 25 | 22 | 20 | 19 | 17 | 16 | 15 | 15 | 13 | 12 | 10 | 8 | 6 | 4 | 2·5 | 1·7 | 0·8 | 0 | 31·1 |
| 29·0 | 23 | 20 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 9 | 7 | 5 | 3 | 2·3 | 1·6 | 0·7 | 0 | 31·0 |
| 29·1 | 20 | 18 | 16 | 15 | 14 | 13 | 13 | 12 | 11 | 10 | 8 | 6 | 5 | 3 | 2·1 | 1·4 | 0·6 | 0 | 30·9 |
| 29·2 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 11 | 9 | 9 | 7 | 6 | 4 | 3 | 1·8 | 1·3 | 0·6 | 0 | 30·8 |
| 29·3 | 16 | 14 | 14 | 13 | 11 | 10 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | 1·6 | 1·1 | 0·5 | 0 | 30·7 |
| 29·4 | 14 | 12 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1·4 | 1·0 | 0·4 | 0 | 30·6 |
| 29·5 | 12 | 10 | 10 | 9 | 8 | 7 | 7 | 7 | 6 | 5 | 4 | 4 | 3 | 2 | 1·1 | 0·8 | 0·3 | 0 | 30·5 |
| 29·6 | 9 | 8 | 8 | 7 | 6 | 6 | 6 | 5 | 5 | 4 | 4 | 3 | 2 | 1 | 0·9 | 0·6 | 0·3 | 0 | 30·4 |
| 29·7 | 6 | 6 | 6 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 1 | 0·7 | 0·5 | 0·2 | 0 | 30·3 |
| 29·8 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0·5 | 0·3 | 0·1 | 0 | 30·2 |
| 29·9 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0·2 | 0·2 | 0·1 | 0 | 30·1 |
| 30·0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30·0 |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. | | |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | ″ of Par. | Corr. for ″ of Par. *add.* 0″ | 2″ | 4″ | 6″ | 8″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ |
| 10 0 | 46 53 | 47 52 | 48 51 | 49 50 | 50 49 | 51 48 | 52 47 | 53 46 | 54 46 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 46 56 | 47 55 | 48 54 | 49 53 | 50 53 | 51 52 | 52 51 | 53 50 | 54 49 | 10 | 10 | 12 | 14 | 16 | 18 |
| 20 | 47 0 | 47 59 | 48 58 | 49 57 | 50 56 | 51 55 | 52 54 | 53 53 | 54 52 | 20 | 20 | 22 | 24 | 26 | 28 |
| 30 | 47 3 | 48 2 | 49 1 | 50 0 | 50 59 | 51 58 | 52 57 | 53 56 | 54 55 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 6 | 48 5 | 49 4 | 50 2 | 51 1 | 52 0 | 52 59 | 53 58 | 54 57 | 40 | 39 | 41 | 43 | 45 | 47 |
| 50 | 47 8 | 48 7 | 49 6 | 50 5 | 51 4 | 52 3 | 53 2 | 54 1 | 55 0 | 50 | 49 | 51 | 53 | 55 | 57 |
| 11 0 | 47 11 | 48 10 | 49 9 | 50 7 | 51 6 | 52 5 | 53 4 | 54 3 | 55 2 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 13 | 48 12 | 49 11 | 50 10 | 51 9 | 52 7 | 53 6 | 54 5 | 55 4 | 10 | 10 | 12 | 14 | 16 | 18 |
| 20 | 47 15 | 48 14 | 49 13 | 50 12 | 51 11 | 52 9 | 53 8 | 54 7 | 55 6 | 20 | 20 | 22 | 24 | 25 | 27 |
| 30 | 47 17 | 48 16 | 49 15 | 50 14 | 51 13 | 52 11 | 53 10 | 54 9 | 55 8 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 19 | 48 18 | 49 17 | 50 16 | 51 15 | 52 13 | 53 12 | 54 11 | 55 10 | 40 | 39 | 41 | 43 | 45 | 47 |
| 50 | 47 21 | 48 20 | 49 19 | 50 18 | 51 16 | 52 15 | 53 14 | 54 13 | 55 11 | 50 | 49 | 51 | 53 | 55 | 57 |
| 12 0 | 47 23 | 48 22 | 49 21 | 50 19 | 51 18 | 52 17 | 53 15 | 54 14 | 55 13 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 25 | 48 24 | 49 22 | 50 21 | 51 20 | 52 18 | 53 17 | 54 16 | 55 14 | 10 | 10 | 12 | 14 | 16 | 18 |
| 20 | 47 27 | 48 25 | 49 24 | 50 23 | 51 21 | 52 20 | 53 19 | 54 17 | 55 16 | 20 | 20 | 21 | 23 | 25 | 27 |
| 30 | 47 28 | 48 27 | 49 25 | 50 24 | 51 23 | 52 21 | 53 20 | 54 18 | 55 17 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 30 | 48 28 | 49 27 | 50 25 | 51 24 | 52 22 | 53 21 | 54 20 | 55 18 | 40 | 39 | 41 | 43 | 45 | 47 |
| 50 | 47 31 | 48 29 | 49 28 | 50 26 | 51 25 | 52 23 | 53 22 | 54 21 | 55 19 | 50 | 49 | 51 | 53 | 55 | 57 |
| 13 0 | 47 32 | 48 30 | 49 29 | 50 27 | 51 26 | 52 24 | 53 23 | 54 21 | 55 20 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 33 | 48 31 | 49 30 | 50 28 | 51 27 | 52 25 | 53 23 | 54 22 | 55 20 | 10 | 10 | 12 | 14 | 16 | 18 |
| 20 | 47 34 | 48 32 | 49 31 | 50 29 | 51 27 | 52 26 | 53 24 | 54 22 | 55 21 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 35 | 48 33 | 49 31 | 50 30 | 51 28 | 52 26 | 53 25 | 54 23 | 55 21 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 35 | 48 34 | 49 32 | 50 30 | 51 29 | 52 27 | 53 25 | 54 23 | 55 22 | 40 | 39 | 41 | 43 | 45 | 47 |
| 50 | 47 36 | 48 34 | 49 33 | 50 31 | 51 29 | 52 27 | 53 26 | 54 24 | 55 22 | 50 | 49 | 51 | 53 | 54 | 56 |
| 14 0 | 47 37 | 48 35 | 49 33 | 50 31 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 37 | 48 35 | 49 33 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 10 | 10 | 12 | 14 | 15 | 17 |
| 20 | 47 37 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 40 | 39 | 41 | 43 | 45 | 46 |
| 50 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 50 | 48 | 50 | 52 | 54 | 56 |
| 15 0 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 26 | 54 24 | 55 22 | 10 | 10 | 12 | 14 | 15 | 17 |
| 20 | 47 38 | 48 36 | 49 34 | 50 32 | 51 30 | 52 28 | 53 25 | 54 23 | 55 21 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 38 | 48 36 | 49 34 | 50 31 | 51 29 | 52 27 | 53 25 | 54 23 | 55 21 | 30 | 29 | 31 | 33 | 35 | 37 |
| 40 | 47 38 | 48 36 | 49 33 | 50 31 | 51 29 | 52 27 | 53 24 | 54 22 | 55 20 | 40 | 39 | 40 | 42 | 44 | 46 |
| 50 | 47 37 | 48 35 | 49 33 | 50 31 | 51 28 | 52 26 | 53 24 | 54 22 | 55 19 | 50 | 48 | 50 | 52 | 54 | 56 |
| 16 0 | 47 37 | 48 35 | 49 32 | 50 30 | 51 28 | 52 26 | 53 23 | 54 21 | 55 19 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 37 | 48 34 | 49 32 | 50 30 | 51 27 | 52 25 | 53 22 | 54 20 | 55 18 | 10 | 10 | 12 | 13 | 15 | 17 |
| 20 | 47 36 | 48 34 | 49 31 | 50 29 | 51 26 | 52 24 | 53 22 | 54 19 | 55 17 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 35 | 48 33 | 49 31 | 50 28 | 51 26 | 52 23 | 53 21 | 54 18 | 55 16 | 30 | 29 | 31 | 33 | 35 | 36 |
| 40 | 47 35 | 48 32 | 49 30 | 50 27 | 51 25 | 52 22 | 53 20 | 54 17 | 55 15 | 40 | 38 | 40 | 42 | 44 | 46 |
| 50 | 47 34 | 48 32 | 49 29 | 50 26 | 51 24 | 52 21 | 53 19 | 54 16 | 55 14 | 50 | 48 | 50 | 52 | 54 | 56 |
| 17 0 | 47 33 | 48 31 | 49 28 | 50 26 | 51 23 | 52 20 | 53 18 | 54 15 | 55 13 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 33 | 48 30 | 49 27 | 50 25 | 51 22 | 52 19 | 53 17 | 54 14 | 55 11 | 10 | 10 | 12 | 13 | 15 | 17 |
| 20 | 47 32 | 48 29 | 49 26 | 50 24 | 51 21 | 52 18 | 53 15 | 54 13 | 55 10 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 31 | 48 28 | 49 25 | 50 22 | 51 20 | 52 17 | 53 14 | 54 11 | 55 9 | 30 | 29 | 30 | 32 | 34 | 36 |
| 40 | 47 30 | 48 27 | 49 24 | 50 21 | 51 18 | 52 16 | 53 13 | 54 10 | 55 7 | 40 | 38 | 40 | 42 | 44 | 46 |
| 50 | 47 29 | 48 26 | 49 23 | 50 20 | 51 17 | 52 14 | 53 11 | 54 9 | 55 6 | 50 | 48 | 50 | 52 | 53 | 55 |
| 18 0 | 47 28 | 48 25 | 49 22 | 50 19 | 51 16 | 52 13 | 53 10 | 54 7 | 55 4 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 26 | 48 23 | 49 20 | 50 17 | 51 15 | 52 12 | 53 9 | 54 6 | 55 3 | 10 | 9 | 11 | 13 | 15 | 17 |
| 20 | 47 25 | 48 22 | 49 19 | 50 16 | 51 14 | 52 10 | 53 7 | 54 4 | 55 1 | 20 | 19 | 21 | 23 | 25 | 27 |
| 30 | 47 24 | 48 21 | 49 18 | 50 15 | 51 12 | 52 9 | 53 5 | 54 2 | 54 59 | 30 | 28 | 30 | 32 | 34 | 36 |
| 40 | 47 23 | 48 20 | 49 16 | 50 13 | 51 10 | 52 7 | 53 4 | 54 1 | 54 58 | 40 | 38 | 40 | 42 | 44 | 46 |
| 50 | 47 21 | 48 18 | 49 15 | 50 12 | 51 8 | 52 5 | 53 2 | 53 59 | 54 56 | 50 | 47 | 49 | 51 | 53 | 55 |
| 19 0 | 47 20 | 48 17 | 49 13 | 50 10 | 51 7 | 52 4 | 53 0 | 53 57 | 54 54 | 0 | 0 | 2 | 4 | 6 | 8 |
| 10 | 47 18 | 48 15 | 49 12 | 50 8 | 51 5 | 52 2 | 52 59 | 53 55 | 54 52 | 10 | 9 | 11 | 13 | 15 | 17 |
| 20 | 47 17 | 48 13 | 49 10 | 50 7 | 51 3 | 52 0 | 52 57 | 53 53 | 54 50 | 20 | 19 | 21 | 23 | 25 | 26 |
| 30 | 47 15 | 48 12 | 49 8 | 50 5 | 51 2 | 51 58 | 52 55 | 53 51 | 54 48 | 30 | 28 | 30 | 32 | 34 | 36 |
| 40 | 47 14 | 48 10 | 49 7 | 50 3 | 51 0 | 51 56 | 52 53 | 53 49 | 54 46 | 40 | 38 | 40 | 41 | 43 | 45 |
| 50 | 47 12 | 48 8 | 49 5 | 50 1 | 50 58 | 51 54 | 52 51 | 53 47 | 54 44 | 50 | 47 | 49 | 51 | 53 | 55 |

| Cor. for ′ of Alt. | |
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| 7 | 0 |
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## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. | | |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | ″ of Par. | Corr. for ″ of Par. *add.* 0″ | 2″ | 4″ | 6″ | 8″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ |
| 30 0 | 44 14 | 45 6 | 45 58 | 46 50 | 47 42 | 48 34 | 49 26 | 50 18 | 51 10 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 44 10 | 45 2 | 45 54 | 46 46 | 47 38 | 48 30 | 49 21 | 50 13 | 51 5 | 10 | 9 | 10 | 12 | 14 | 16 |
| 20 | 44 6 | 44 58 | 45 50 | 46 42 | 47 33 | 48 25 | 49 17 | 50 9 | 51 1 | 20 | 17 | 19 | 21 | 22 | 24 |
| 30 | 44 2 | 44 54 | 45 46 | 46 37 | 47 29 | 48 21 | 49 12 | 50 4 | 50 56 | 30 | 26 | 28 | 29 | 31 | 33 |
| 40 | 43 58 | 44 50 | 45 41 | 46 33 | 47 25 | 48 16 | 49 8 | 49 59 | 50 51 | 40 | 34 | 36 | 38 | 40 | 41 |
| 50 | 43 54 | 44 45 | 45 37 | 46 29 | 47 20 | 48 12 | 49 3 | 49 55 | 50 46 | 50 | 43 | 45 | 47 | 48 | 50 |
| 31 0 | 43 50 | 44 41 | 45 33 | 46 24 | 47 16 | 48 7 | 48 58 | 49 50 | 50 41 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 43 46 | 44 37 | 45 28 | 46 20 | 47 11 | 48 2 | 48 54 | 49 45 | 50 37 | 10 | 9 | 10 | 12 | 14 | 16 |
| 20 | 43 41 | 44 33 | 45 24 | 46 15 | 47 7 | 47 58 | 48 49 | 49 40 | 50 32 | 20 | 17 | 19 | 20 | 22 | 24 |
| 30 | 43 37 | 44 28 | 45 20 | 46 11 | 47 2 | 47 53 | 48 44 | 49 35 | 50 27 | 30 | 26 | 27 | 29 | 31 | 32 |
| 40 | 43 33 | 44 24 | 45 15 | 46 6 | 46 57 | 47 48 | 48 39 | 49 31 | 50 22 | 40 | 34 | 36 | 38 | 39 | 41 |
| 50 | 43 29 | 44 20 | 45 11 | 46 2 | 46 53 | 47 44 | 48 35 | 49 26 | 50 17 | 50 | 43 | 44 | 46 | 48 | 49 |
| 32 0 | 43 24 | 44 15 | 45 6 | 45 57 | 46 48 | 47 39 | 48 30 | 49 21 | 50 12 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 43 20 | 44 11 | 45 2 | 45 53 | 46 43 | 47 34 | 48 25 | 49 16 | 50 7 | 10 | 8 | 10 | 12 | 13 | 15 |
| 20 | 43 16 | 44 6 | 44 57 | 45 48 | 46 39 | 47 29 | 48 20 | 49 11 | 50 1 | 20 | 17 | 19 | 20 | 22 | 24 |
| 30 | 43 11 | 44 2 | 44 53 | 45 43 | 46 34 | 47 24 | 48 15 | 49 6 | 49 56 | 30 | 25 | 27 | 29 | 30 | 32 |
| 40 | 43 7 | 43 57 | 44 48 | 45 39 | 46 29 | 47 20 | 48 10 | 49 1 | 49 51 | 40 | 34 | 35 | 37 | 39 | 41 |
| 50 | 43 3 | 43 53 | 44 43 | 45 34 | 46 24 | 47 15 | 48 5 | 48 56 | 49 46 | 50 | 42 | 44 | 46 | 47 | 49 |
| 33 0 | 42 58 | 43 48 | 44 39 | 45 29 | 46 19 | 47 10 | 48 0 | 48 50 | 49 41 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 42 54 | 43 44 | 44 34 | 45 24 | 46 15 | 47 5 | 47 55 | 48 45 | 49 36 | 10 | 8 | 10 | 12 | 13 | 15 |
| 20 | 42 49 | 43 39 | 44 29 | 45 20 | 46 10 | 47 0 | 47 50 | 48 40 | 49 30 | 20 | 17 | 18 | 20 | 22 | 23 |
| 30 | 42 45 | 43 35 | 44 24 | 45 15 | 46 5 | 46 55 | 47 45 | 48 35 | 49 25 | 30 | 25 | 27 | 28 | 30 | 32 |
| 40 | 42 40 | 43 30 | 44 19 | 45 10 | 46 0 | 46 50 | 47 40 | 48 30 | 49 20 | 40 | 33 | 35 | 37 | 38 | 40 |
| 50 | 42 35 | 43 25 | 44 14 | 45 5 | 45 55 | 46 45 | 47 35 | 48 24 | 49 14 | 50 | 42 | 44 | 45 | 47 | 48 |
| 34 0 | 42 31 | 43 21 | 44 10 | 45 0 | 45 50 | 46 40 | 47 29 | 48 19 | 49 9 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 42 26 | 43 16 | 44 6 | 44 55 | 45 45 | 46 34 | 47 24 | 48 14 | 49 3 | 10 | 8 | 10 | 12 | 13 | 15 |
| 20 | 42 21 | 43 11 | 44 1 | 44 50 | 45 40 | 46 29 | 47 19 | 48 8 | 48 58 | 20 | 16 | 18 | 20 | 21 | 23 |
| 30 | 42 17 | 43 6 | 43 56 | 44 45 | 45 35 | 46 24 | 47 14 | 48 3 | 48 53 | 30 | 25 | 27 | 28 | 30 | 31 |
| 40 | 42 12 | 43 1 | 43 51 | 44 40 | 45 30 | 46 19 | 47 8 | 47 58 | 48 47 | 40 | 33 | 35 | 36 | 38 | 40 |
| 50 | 42 7 | 42 57 | 43 46 | 44 35 | 45 24 | 46 14 | 47 3 | 47 52 | 48 41 | 50 | 41 | 43 | 44 | 46 | 48 |
| 35 0 | 42 3 | 42 52 | 43 41 | 44 30 | 45 19 | 46 8 | 46 57 | 47 47 | 48 36 | 0 | 0 | 2 | 3 | 5 | 7 |
| 10 | 41 58 | 42 47 | 43 36 | 44 25 | 45 14 | 46 3 | 46 52 | 47 41 | 48 30 | 10 | 8 | 10 | 11 | 13 | 15 |
| 20 | 41 53 | 42 42 | 43 31 | 44 20 | 45 9 | 45 58 | 46 47 | 47 36 | 48 25 | 20 | 16 | 18 | 20 | 21 | 23 |
| 30 | 41 48 | 42 37 | 43 26 | 44 15 | 45 3 | 45 52 | 46 41 | 47 30 | 48 19 | 30 | 24 | 26 | 28 | 29 | 31 |
| 40 | 41 43 | 42 32 | 43 21 | 44 9 | 44 58 | 45 47 | 46 36 | 47 24 | 48 13 | 40 | 33 | 34 | 36 | 38 | 39 |
| 50 | 41 38 | 42 27 | 43 16 | 44 4 | 44 53 | 45 41 | 46 30 | 47 19 | 48 7 | 50 | 41 | 42 | 44 | 46 | 47 |
| 36 0 | 41 33 | 42 22 | 43 10 | 43 59 | 44 48 | 45 36 | 46 25 | 47 13 | 48 2 | 0 | 0 | 2 | 3 | 5 | 6 |
| 10 | 41 28 | 42 17 | 43 5 | 43 54 | 44 42 | 45 31 | 46 19 | 47 7 | 47 56 | 10 | 8 | 10 | 11 | 13 | 14 |
| 20 | 41 23 | 42 12 | 43 0 | 43 48 | 44 37 | 45 25 | 46 13 | 47 2 | 47 50 | 20 | 16 | 18 | 19 | 21 | 23 |
| 30 | 41 18 | 42 7 | 42 55 | 43 43 | 44 31 | 45 20 | 46 8 | 46 56 | 47 44 | 30 | 24 | 26 | 27 | 29 | 31 |
| 40 | 41 13 | 42 1 | 42 50 | 43 38 | 44 26 | 45 14 | 46 2 | 46 50 | 47 38 | 40 | 32 | 34 | 35 | 37 | 39 |
| 50 | 41 8 | 41 56 | 42 44 | 43 32 | 44 20 | 45 8 | 45 56 | 46 44 | 47 33 | 50 | 40 | 42 | 44 | 45 | 47 |
| 37 0 | 41 3 | 41 51 | 42 39 | 43 27 | 44 15 | 45 3 | 45 51 | 46 39 | 47 27 | 0 | 0 | 2 | 3 | 5 | 6 |
| 10 | 40 58 | 41 46 | 42 34 | 43 22 | 44 9 | 44 57 | 45 45 | 46 33 | 47 21 | 10 | 8 | 10 | 11 | 13 | 14 |
| 20 | 40 53 | 41 41 | 42 28 | 43 16 | 44 4 | 44 52 | 45 39 | 46 27 | 47 15 | 20 | 16 | 17 | 19 | 21 | 22 |
| 30 | 40 48 | 41 35 | 42 23 | 43 11 | 43 58 | 44 46 | 45 33 | 46 21 | 47 9 | 30 | 24 | 26 | 28 | 29 | 31 |
| 40 | 40 43 | 41 30 | 42 18 | 43 5 | 43 53 | 44 40 | 45 28 | 46 15 | 47 3 | 40 | 32 | 34 | 35 | 37 | 38 |
| 50 | 40 37 | 41 25 | 42 12 | 43 0 | 43 47 | 44 34 | 45 22 | 46 9 | 46 57 | 50 | 40 | 41 | 43 | 44 | 46 |
| 38 0 | 40 32 | 41 19 | 42 7 | 42 54 | 43 41 | 44 29 | 45 16 | 46 3 | 46 51 | 0 | 0 | 2 | 3 | 5 | 6 |
| 10 | 40 27 | 41 14 | 42 1 | 42 48 | 43 36 | 44 23 | 45 10 | 45 57 | 46 44 | 10 | 8 | 9 | 11 | 12 | 14 |
| 20 | 40 22 | 41 9 | 41 56 | 42 43 | 43 30 | 44 17 | 45 4 | 45 51 | 46 38 | 20 | 16 | 17 | 19 | 20 | 22 |
| 30 | 40 16 | 41 3 | 41 50 | 42 37 | 43 24 | 44 11 | 44 58 | 45 45 | 46 32 | 30 | 23 | 25 | 27 | 28 | 30 |
| 40 | 40 11 | 40 58 | 41 45 | 42 32 | 43 18 | 44 5 | 44 52 | 45 39 | 46 26 | 40 | 31 | 33 | 35 | 36 | 38 |
| 50 | 40 6 | 40 52 | 41 39 | 42 26 | 43 13 | 43 59 | 44 46 | 45 33 | 46 20 | 50 | 39 | 41 | 42 | 44 | 45 |
| 39 0 | 40 0 | 40 47 | 41 33 | 42 20 | 43 7 | 43 53 | 44 40 | 45 27 | 46 13 | 0 | 0 | 2 | 3 | 5 | 6 |
| 10 | 39 55 | 40 41 | 41 28 | 42 14 | 43 1 | 43 47 | 44 34 | 45 21 | 46 7 | 10 | 8 | 9 | 11 | 12 | 14 |
| 20 | 39 49 | 40 36 | 41 22 | 42 9 | 42 55 | 43 41 | 44 28 | 45 14 | 46 1 | 20 | 15 | 17 | 19 | 20 | 22 |
| 30 | 39 44 | 40 30 | 41 17 | 42 3 | 42 49 | 43 35 | 44 22 | 45 8 | 45 54 | 30 | 23 | 25 | 27 | 28 | 30 |
| 40 | 39 38 | 40 25 | 41 11 | 41 57 | 42 43 | 43 29 | 44 16 | 45 2 | 45 48 | 40 | 31 | 32 | 34 | 36 | 37 |
| 50 | 39 33 | 40 19 | 41 5 | 41 51 | 42 37 | 43 23 | 44 9 | 44 56 | 45 42 | 50 | 39 | 40 | 42 | 43 | 45 |

Cor. for ′ of Alt.

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## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | ″ of Par. | Corr. for ″ of Par. *add.* 0″ | 2″ | 4″ | 6″ | 8″ | Cor. for ′ of Alt. |
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| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ | |
| 40 0 | 39 27 | 40 13 | 40 59 | 41 45 | 42 31 | 43 17 | 44 3 | 44 49 | 45 35 | 0 | 0 | 1 | 3 | 5 | 6 | |
| 10 | 39 22 | 40 8 | 40 54 | 41 39 | 42 25 | 43 11 | 43 57 | 44 43 | 45 29 | 10 | 8 | 9 | 11 | 12 | 14 | |
| 20 | 39 16 | 40 2 | 40 48 | 41 33 | 42 19 | 43 5 | 43 51 | 44 36 | 45 22 | 20 | 15 | 17 | 18 | 20 | 21 | |
| 30 | 39 11 | 39 56 | 40 42 | 41 28 | 42 13 | 42 59 | 43 44 | 44 30 | 45 16 | 30 | 23 | 24 | 26 | 27 | 29 | |
| 40 | 39 5 | 39 51 | 40 36 | 41 22 | 42 7 | 42 53 | 43 38 | 44 24 | 45 9 | 40 | 30 | 32 | 33 | 35 | 36 | |
| 50 | 38 59 | 39 45 | 40 30 | 41 16 | 42 1 | 42 46 | 43 32 | 44 17 | 45 3 | 50 | 38 | 40 | 41 | 43 | 44 | |
| 41 0 | 38 54 | 39 39 | 40 24 | 41 10 | 41 55 | 42 40 | 43 25 | 44 11 | 44 56 | 0 | 0 | 1 | 3 | 4 | 6 | |
| 10 | 38 48 | 39 33 | 40 18 | 41 4 | 41 49 | 42 34 | 43 19 | 44 4 | 44 49 | 10 | 7 | 9 | 10 | 12 | 14 | |
| 20 | 38 42 | 39 27 | 40 12 | 40 58 | 41 43 | 42 28 | 43 13 | 43 58 | 44 43 | 20 | 15 | 16 | 18 | 19 | 21 | |
| 30 | 38 37 | 39 22 | 40 6 | 40 51 | 41 36 | 42 21 | 43 6 | 43 51 | 44 36 | 30 | 22 | 24 | 25 | 27 | 28 | |
| 40 | 38 31 | 39 16 | 40 0 | 40 45 | 41 30 | 42 15 | 43 0 | 43 45 | 44 30 | 40 | 30 | 31 | 33 | 34 | 36 | |
| 50 | 38 25 | 39 10 | 39 54 | 40 39 | 41 24 | 42 9 | 42 53 | 43 38 | 44 23 | 50 | 37 | 39 | 40 | 42 | 43 | |
| 42 0 | 38 19 | 39 4 | 39 48 | 40 33 | 41 18 | 42 2 | 42 47 | 43 31 | 44 16 | 0 | 0 | 1 | 3 | 4 | 6 | |
| 10 | 38 13 | 38 58 | 39 42 | 40 27 | 41 11 | 41 56 | 42 40 | 43 25 | 44 9 | 10 | 7 | 9 | 10 | 12 | 13 | |
| 20 | 38 8 | 38 52 | 39 36 | 40 21 | 41 5 | 41 49 | 42 34 | 43 18 | 44 3 | 20 | 15 | 16 | 18 | 19 | 21 | |
| 30 | 38 2 | 38 46 | 39 30 | 40 14 | 40 59 | 41 43 | 42 27 | 43 11 | 43 56 | 30 | 22 | 24 | 25 | 27 | 28 | |
| 40 | 37 56 | 38 40 | 39 24 | 40 8 | 40 52 | 41 36 | 42 21 | 43 5 | 43 49 | 40 | 29 | 31 | 32 | 34 | 36 | *sub.* |
| 50 | 37 50 | 38 34 | 39 18 | 40 2 | 40 46 | 41 30 | 42 14 | 42 58 | 43 42 | 50 | 37 | 38 | 40 | 41 | 43 | ′ ″ |
| 43 0 | 37 44 | 38 28 | 39 12 | 39 56 | 40 40 | 41 23 | 42 7 | 42 51 | 43 35 | 0 | 0 | 1 | 3 | 4 | 6 | 1 1 |
| 10 | 37 38 | 38 22 | 39 6 | 39 49 | 40 33 | 41 17 | 42 1 | 42 44 | 43 28 | 10 | 7 | 9 | 10 | 12 | 13 | 2 1 |
| 20 | 37 32 | 38 16 | 38 59 | 39 43 | 40 27 | 41 10 | 41 54 | 42 38 | 43 21 | 20 | 15 | 16 | 17 | 19 | 21 | 3 2 |
| 30 | 37 26 | 38 10 | 38 53 | 39 37 | 40 20 | 41 4 | 41 47 | 42 31 | 43 14 | 30 | 22 | 23 | 25 | 26 | 28 | 4 3 |
| 40 | 37 20 | 38 3 | 38 47 | 39 30 | 40 14 | 40 57 | 41 40 | 42 24 | 43 7 | 40 | 29 | 30 | 32 | 33 | 35 | 5 3 |
| 50 | 37 14 | 37 57 | 38 41 | 39 24 | 40 7 | 40 50 | 41 34 | 42 17 | 43 0 | 50 | 36 | 38 | 39 | 41 | 42 | 6 4 |
| 44 0 | 37 8 | 37 51 | 38 34 | 39 17 | 40 1 | 40 44 | 41 27 | 42 10 | 42 53 | 0 | 0 | 1 | 3 | 4 | 6 | 7 5 |
| 10 | 37 2 | 37 45 | 38 28 | 39 11 | 39 54 | 40 37 | 41 20 | 42 3 | 42 46 | 10 | 7 | 9 | 10 | 11 | 13 | 8 6 |
| 20 | 36 56 | 37 39 | 38 21 | 39 4 | 39 47 | 40 30 | 41 13 | 41 56 | 42 39 | 20 | 14 | 16 | 17 | 19 | 21 | 9 6 |
| 30 | 36 50 | 37 32 | 38 15 | 38 58 | 39 41 | 40 24 | 41 6 | 41 49 | 42 32 | 30 | 22 | 23 | 24 | 26 | 27 | |
| 40 | 36 43 | 37 26 | 38 9 | 38 51 | 39 34 | 40 17 | 40 59 | 41 42 | 42 25 | 40 | 29 | 30 | 31 | 33 | 34 | |
| 50 | 36 37 | 37 20 | 38 2 | 38 45 | 39 27 | 40 10 | 40 53 | 41 35 | 42 18 | 50 | 36 | 37 | 39 | 40 | 41 | |
| 45 0 | 36 31 | 37 13 | 37 56 | 38 38 | 39 21 | 40 3 | 40 46 | 41 28 | 42 11 | 0 | 0 | 1 | 3 | 4 | 6 | |
| 10 | 36 25 | 37 7 | 37 49 | 38 32 | 39 14 | 39 56 | 40 39 | 41 21 | 42 3 | 10 | 7 | 8 | 10 | 11 | 13 | |
| 20 | 36 19 | 37 1 | 37 43 | 38 25 | 39 7 | 39 50 | 40 32 | 41 14 | 41 56 | 20 | 14 | 15 | 17 | 18 | 20 | |
| 30 | 36 12 | 36 54 | 37 36 | 38 19 | 39 1 | 39 43 | 40 25 | 41 7 | 41 49 | 30 | 21 | 22 | 24 | 25 | 27 | |
| 40 | 36 6 | 36 48 | 37 30 | 38 12 | 38 54 | 39 36 | 40 18 | 41 0 | 41 42 | 40 | 28 | 29 | 31 | 32 | 34 | |
| 50 | 36 0 | 36 42 | 37 23 | 38 5 | 38 47 | 39 29 | 40 11 | 40 52 | 41 34 | 50 | 35 | 36 | 38 | 39 | 41 | |
| 46 0 | 35 53 | 36 35 | 37 17 | 37 59 | 38 40 | 39 22 | 40 4 | 40 45 | 41 27 | 0 | 0 | 1 | 3 | 4 | 6 | |
| 10 | 35 47 | 36 29 | 37 10 | 37 52 | 38 33 | 39 15 | 39 56 | 40 38 | 41 20 | 10 | 7 | 8 | 10 | 11 | 12 | |
| 20 | 35 41 | 36 22 | 37 4 | 37 45 | 38 26 | 39 8 | 39 49 | 40 31 | 41 12 | 20 | 14 | 15 | 17 | 18 | 19 | |
| 30 | 35 34 | 36 16 | 36 57 | 37 38 | 38 20 | 39 1 | 39 42 | 40 24 | 41 5 | 30 | 21 | 22 | 23 | 25 | 26 | |
| 40 | 35 28 | 36 9 | 36 50 | 37 32 | 38 13 | 38 54 | 39 35 | 40 16 | 40 57 | 40 | 28 | 29 | 30 | 32 | 33 | |
| 50 | 35 22 | 36 3 | 36 44 | 37 25 | 38 6 | 38 47 | 39 28 | 40 9 | 40 50 | 50 | 34 | 36 | 37 | 39 | 40 | |
| 47 0 | 35 15 | 35 56 | 36 37 | 37 18 | 37 59 | 38 40 | 39 21 | 40 2 | 40 43 | 0 | 0 | 1 | 3 | 4 | 5 | |
| 10 | 35 9 | 35 49 | 36 30 | 37 11 | 37 52 | 38 33 | 39 13 | 39 54 | 40 35 | 10 | 7 | 8 | 9 | 11 | 12 | |
| 20 | 35 2 | 35 43 | 36 23 | 37 4 | 37 45 | 38 25 | 39 6 | 39 47 | 40 28 | 20 | 14 | 15 | 16 | 18 | 19 | |
| 30 | 34 56 | 35 36 | 36 17 | 36 57 | 37 38 | 38 18 | 38 59 | 39 39 | 40 20 | 30 | 20 | 22 | 23 | 24 | 26 | |
| 40 | 34 49 | 35 29 | 36 10 | 36 50 | 37 31 | 38 11 | 38 52 | 39 32 | 40 12 | 40 | 27 | 28 | 30 | 31 | 32 | |
| 50 | 34 43 | 35 23 | 36 3 | 36 43 | 37 24 | 38 4 | 38 44 | 39 25 | 40 5 | 50 | 34 | 35 | 37 | 38 | 39 | |
| 48 0 | 34 36 | 35 16 | 35 56 | 36 36 | 37 17 | 37 57 | 38 37 | 39 17 | 39 57 | 0 | 0 | 1 | 3 | 4 | 5 | ′ ″ |
| 10 | 34 29 | 35 9 | 35 49 | 36 30 | 37 10 | 37 50 | 38 30 | 39 10 | 39 50 | 10 | 7 | 8 | 9 | 11 | 12 | 1 1 |
| 20 | 34 23 | 35 3 | 35 43 | 36 23 | 37 2 | 37 42 | 38 22 | 39 2 | 39 42 | 20 | 13 | 15 | 16 | 17 | 19 | 2 1 |
| 30 | 34 16 | 34 56 | 35 36 | 36 16 | 36 55 | 37 35 | 38 15 | 38 55 | 39 34 | 30 | 20 | 21 | 23 | 24 | 25 | 3 2 |
| 40 | 34 10 | 34 49 | 35 29 | 36 8 | 36 48 | 37 28 | 38 7 | 38 47 | 39 27 | 40 | 27 | 28 | 29 | 30 | 32 | 4 3 |
| 50 | 34 3 | 34 42 | 35 22 | 36 1 | 36 41 | 37 20 | 38 0 | 38 39 | 39 19 | 50 | 33 | 34 | 36 | 37 | 38 | 5 4 |
| 49 0 | 33 56 | 34 36 | 35 15 | 35 54 | 36 34 | 37 13 | 37 52 | 38 32 | 39 11 | 0 | 0 | 1 | 3 | 4 | 5 | 6 4 |
| 10 | 33 50 | 34 29 | 35 8 | 35 47 | 36 27 | 37 6 | 37 45 | 38 24 | 39 3 | 10 | 6 | 8 | 9 | 10 | 12 | 7 5 |
| 20 | 33 43 | 34 22 | 35 1 | 35 40 | 36 19 | 36 58 | 37 37 | 38 17 | 38 56 | 20 | 13 | 14 | 16 | 17 | 19 | 8 6 |
| 30 | 33 36 | 34 15 | 34 54 | 35 33 | 36 12 | 36 51 | 37 30 | 38 9 | 38 48 | 30 | 20 | 21 | 22 | 23 | 25 | 9 7 |
| 40 | 33 29 | 34 8 | 34 47 | 35 26 | 36 5 | 36 44 | 37 22 | 38 1 | 38 40 | 40 | 26 | 27 | 29 | 30 | 31 | |
| 50 | 33 23 | 34 1 | 34 40 | 35 19 | 35 57 | 36 36 | 37 15 | 37 54 | 38 32 | 50 | 32 | 34 | 35 | 36 | 38 | |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. | | | | | | | | | ″ of Par. | Corr. for ″ of Par. *add.* | | | | | Cor. for ′ of Alt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | | 0″ | 2″ | 4″ | 6″ | 8″ | |
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ | |
| 50 0 | 33 16 | 33 54 | 34 33 | 35 11 | 35 50 | 36 29 | 37 7 | 37 46 | 38 24 | 0 | 0 | 1 | 3 | 4 | 5 | |
| 10 | 33 9 | 33 47 | 34 26 | 35 4 | 35 43 | 36 21 | 37 0 | 37 38 | 38 16 | 10 | 6 | 7 | 9 | 10 | 11 | |
| 20 | 33 2 | 33 40 | 34 19 | 34 57 | 35 35 | 36 14 | 36 52 | 37 30 | 38 9 | 20 | 13 | 14 | 15 | 17 | 18 | |
| 30 | 32 55 | 33 33 | 34 12 | 34 50 | 35 28 | 36 6 | 36 44 | 37 22 | 38 1 | 30 | 19 | 20 | 22 | 23 | 24 | *sub.* |
| 40 | 32 48 | 33 26 | 34 4 | 34 42 | 35 21 | 35 59 | 36 37 | 37 15 | 37 53 | 40 | 25 | 27 | 28 | 29 | 31 | ′ ″ |
| 50 | 32 42 | 33 19 | 33 57 | 34 35 | 35 13 | 35 51 | 36 29 | 37 7 | 37 45 | 50 | 32 | 33 | 34 | 36 | 37 | 1 1 |
| 51 0 | 32 35 | 33 12 | 33 50 | 34 28 | 35 6 | 35 43 | 36 21 | 36 59 | 37 37 | 0 | 0 | 1 | 2 | 4 | 5 | 2 2 |
| 10 | 32 28 | 33 5 | 33 43 | 34 21 | 34 58 | 35 36 | 36 13 | 36 51 | 37 29 | 10 | 6 | 7 | 9 | 10 | 11 | 3 2 |
| 20 | 32 21 | 32 58 | 33 36 | 34 13 | 34 51 | 35 28 | 36 6 | 36 43 | 37 21 | 20 | 12 | 14 | 15 | 16 | 17 | 4 3 |
| 30 | 32 14 | 32 51 | 33 29 | 34 6 | 34 43 | 35 21 | 35 58 | 36 35 | 37 13 | 30 | 19 | 20 | 21 | 22 | 24 | 5 4 |
| 40 | 32 7 | 32 44 | 33 21 | 33 59 | 34 36 | 35 13 | 35 50 | 36 27 | 37 5 | 40 | 25 | 26 | 28 | 29 | 30 | 6 4 |
| 50 | 32 0 | 32 37 | 33 14 | 33 51 | 34 28 | 35 5 | 35 42 | 36 19 | 36 57 | 50 | 31 | 32 | 34 | 35 | 36 | 7 5 |
| 52 0 | 31 53 | 32 30 | 33 7 | 33 44 | 34 21 | 34 58 | 35 35 | 36 11 | 36 48 | 0 | 0 | 1 | 2 | 4 | 5 | 8 6 |
| 10 | 31 46 | 32 23 | 32 59 | 33 36 | 34 13 | 34 50 | 35 27 | 36 3 | 36 40 | 10 | 6 | 7 | 9 | 10 | 11 | 9 7 |
| 20 | 31 39 | 32 15 | 32 52 | 33 29 | 34 5 | 34 42 | 35 19 | 35 55 | 36 32 | 20 | 12 | 13 | 15 | 16 | 17 | |
| 30 | 31 32 | 32 8 | 32 45 | 33 21 | 33 58 | 34 34 | 35 11 | 35 47 | 36 24 | 30 | 18 | 19 | 21 | 22 | 23 | |
| 40 | 31 25 | 32 1 | 32 37 | 33 14 | 33 50 | 34 27 | 35 3 | 35 39 | 36 16 | 40 | 24 | 26 | 27 | 28 | 29 | |
| 50 | 31 17 | 31 54 | 32 30 | 33 6 | 33 43 | 34 19 | 34 55 | 35 31 | 36 8 | 50 | 30 | 32 | 33 | 34 | 35 | |
| 53 0 | 31 10 | 31 47 | 32 23 | 32 59 | 33 35 | 34 11 | 34 47 | 35 23 | 35 59 | 0 | 0 | 1 | 2 | 4 | 5 | ′ ″ |
| 10 | 31 3 | 31 39 | 32 15 | 32 51 | 33 27 | 34 3 | 34 39 | 35 15 | 35 51 | 10 | 6 | 7 | 8 | 10 | 11 | 1 1 |
| 20 | 30 56 | 31 32 | 32 8 | 32 44 | 33 19 | 33 55 | 34 31 | 35 7 | 35 43 | 20 | 12 | 13 | 14 | 15 | 17 | 2 2 |
| 30 | 30 49 | 31 25 | 32 0 | 32 36 | 33 12 | 33 47 | 34 23 | 34 59 | 35 35 | 30 | 18 | 19 | 20 | 21 | 23 | 3 2 |
| 40 | 30 42 | 31 17 | 31 53 | 32 28 | 33 4 | 33 40 | 34 15 | 34 51 | 35 26 | 40 | 24 | 25 | 26 | 27 | 29 | 4 3 |
| 50 | 30 35 | 31 10 | 31 45 | 32 21 | 32 56 | 33 32 | 34 7 | 34 42 | 35 18 | 50 | 30 | 31 | 32 | 33 | 35 | 5 4 |
| 54 0 | 30 27 | 31 3 | 31 38 | 32 13 | 32 48 | 33 24 | 33 59 | 34 34 | 35 10 | 0 | 0 | 1 | 2 | 3 | 5 | 6 5 |
| 10 | 30 20 | 30 55 | 31 30 | 32 6 | 32 41 | 33 16 | 33 51 | 34 26 | 35 1 | 10 | 6 | 7 | 8 | 9 | 10 | 7 6 |
| 20 | 30 13 | 30 48 | 31 23 | 31 58 | 32 33 | 33 8 | 33 43 | 34 18 | 34 53 | 20 | 12 | 13 | 14 | 15 | 16 | 8 6 |
| 30 | 30 6 | 30 40 | 31 15 | 31 50 | 32 25 | 33 0 | 33 35 | 34 10 | 34 44 | 30 | 17 | 19 | 20 | 21 | 22 | 9 7 |
| 40 | 29 58 | 30 33 | 31 8 | 31 42 | 32 17 | 32 52 | 33 27 | 34 1 | 34 36 | 40 | 23 | 24 | 26 | 27 | 28 | |
| 50 | 29 51 | 30 26 | 31 0 | 31 35 | 32 9 | 32 44 | 33 18 | 33 53 | 34 28 | 50 | 29 | 30 | 31 | 32 | 34 | |
| 55 0 | 29 44 | 30 18 | 30 53 | 31 27 | 32 1 | 32 36 | 33 10 | 33 45 | 34 19 | 0 | 0 | 1 | 2 | 3 | 5 | |
| 10 | 29 36 | 30 11 | 30 45 | 31 19 | 31 54 | 32 28 | 33 2 | 33 36 | 34 11 | 10 | 6 | 7 | 8 | 9 | 10 | |
| 20 | 29 29 | 30 3 | 30 37 | 31 11 | 31 46 | 32 20 | 32 54 | 33 28 | 34 2 | 20 | 11 | 12 | 14 | 15 | 16 | |
| 30 | 29 22 | 29 56 | 30 30 | 31 4 | 31 38 | 32 12 | 32 46 | 33 20 | 33 54 | 30 | 17 | 18 | 19 | 20 | 22 | |
| 40 | 29 14 | 29 48 | 30 22 | 30 56 | 31 30 | 32 3 | 32 37 | 33 11 | 33 45 | 40 | 23 | 24 | 25 | 26 | 27 | ′ ″ |
| 50 | 29 7 | 29 41 | 30 14 | 30 48 | 31 22 | 31 55 | 32 29 | 33 3 | 33 37 | 50 | 28 | 29 | 31 | 32 | 33 | 1 1 |
| 56 0 | 28 59 | 29 33 | 30 7 | 30 40 | 31 14 | 31 47 | 32 21 | 32 54 | 33 28 | 0 | 0 | 1 | 2 | 3 | 4 | 2 2 |
| 10 | 28 52 | 29 25 | 29 59 | 30 32 | 31 6 | 31 39 | 32 12 | 32 46 | 33 19 | 10 | 6 | 7 | 8 | 9 | 10 | 3 2 |
| 20 | 28 45 | 29 18 | 29 51 | 30 24 | 30 58 | 31 31 | 32 4 | 32 37 | 33 11 | 20 | 11 | 12 | 13 | 14 | 15 | 4 3 |
| 30 | 28 37 | 29 10 | 29 43 | 30 16 | 30 50 | 31 23 | 31 56 | 32 29 | 33 2 | 30 | 17 | 18 | 19 | 20 | 21 | 5 4 |
| 40 | 28 30 | 29 3 | 29 36 | 30 9 | 30 42 | 31 15 | 31 48 | 32 20 | 32 53 | 40 | 22 | 23 | 24 | 25 | 26 | 6 5 |
| 50 | 28 22 | 28 55 | 29 28 | 30 1 | 30 33 | 31 6 | 31 39 | 32 12 | 32 45 | 50 | 28 | 29 | 30 | 31 | 32 | 7 6 |
| 57 0 | 28 15 | 28 47 | 29 20 | 29 53 | 30 25 | 30 58 | 31 31 | 32 3 | 32 36 | 0 | 0 | 1 | 2 | 3 | 4 | 8 6 |
| 10 | 28 7 | 28 40 | 29 12 | 29 45 | 30 17 | 30 50 | 31 22 | 31 55 | 32 27 | 10 | 5 | 7 | 8 | 9 | 10 | 9 7 |
| 20 | 28 0 | 28 32 | 29 4 | 29 37 | 30 9 | 30 42 | 31 14 | 31 46 | 32 19 | 20 | 11 | 12 | 13 | 14 | 15 | |
| 30 | 27 52 | 28 24 | 28 56 | 29 29 | 30 1 | 30 33 | 31 5 | 31 38 | 32 10 | 30 | 16 | 17 | 18 | 19 | 20 | |
| 40 | 27 44 | 28 17 | 28 49 | 29 21 | 29 53 | 30 25 | 30 57 | 31 29 | 32 1 | 40 | 21 | 22 | 23 | 24 | 26 | |
| 50 | 27 37 | 28 9 | 28 41 | 29 13 | 29 45 | 30 17 | 30 49 | 31 20 | 31 52 | 50 | 27 | 28 | 29 | 30 | 31 | |
| 58 0 | 27 29 | 28 1 | 28 33 | 29 5 | 29 36 | 30 8 | 30 40 | 31 12 | 31 44 | 0 | 0 | 1 | 2 | 3 | 4 | ′ ″ |
| 10 | 27 22 | 27 53 | 28 25 | 28 57 | 29 28 | 30 0 | 30 32 | 31 3 | 31 35 | 10 | 5 | 6 | 7 | 8 | 9 | 1 1 |
| 20 | 27 14 | 27 45 | 28 17 | 28 48 | 29 20 | 29 51 | 30 23 | 30 55 | 31 26 | 20 | 10 | 11 | 13 | 14 | 15 | 2 2 |
| 30 | 27 6 | 27 38 | 28 9 | 28 40 | 29 12 | 29 43 | 30 14 | 30 46 | 31 17 | 30 | 16 | 17 | 18 | 19 | 20 | 3 2 |
| 40 | 26 59 | 27 30 | 28 1 | 28 32 | 29 3 | 29 35 | 30 6 | 30 37 | 31 8 | 40 | 21 | 22 | 23 | 24 | 25 | 4 3 |
| 50 | 26 51 | 27 22 | 27 53 | 28 24 | 28 55 | 29 26 | 29 57 | 30 28 | 30 59 | 50 | 26 | 27 | 28 | 29 | 30 | 5 4 |
| 59 0 | 26 43 | 27 14 | 27 45 | 28 16 | 28 47 | 29 18 | 29 49 | 30 20 | 30 51 | 0 | 0 | 1 | 2 | 3 | 4 | 6 5 |
| 10 | 26 36 | 27 6 | 27 37 | 28 8 | 28 39 | 29 9 | 29 40 | 30 11 | 30 42 | 10 | 5 | 6 | 7 | 8 | 9 | 7 6 |
| 20 | 26 28 | 26 58 | 27 29 | 28 0 | 28 30 | 29 1 | 29 32 | 30 2 | 30 33 | 20 | 10 | 11 | 12 | 13 | 14 | 8 7 |
| 30 | 26 20 | 26 51 | 27 21 | 27 52 | 28 22 | 28 52 | 29 23 | 29 53 | 30 24 | 30 | 15 | 16 | 17 | 18 | 19 | 9 7 |
| 40 | 26 12 | 26 43 | 27 13 | 27 43 | 28 14 | 28 44 | 29 14 | 29 45 | 30 15 | 40 | 20 | 21 | 22 | 23 | 24 | |
| 50 | 26 5 | 26 35 | 27 5 | 27 35 | 28 5 | 28 35 | 29 6 | 29 36 | 30 6 | 50 | 25 | 26 | 27 | 28 | 29 | |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. | | | | | | | | | " of Par. | Corr. for " of Par. *add.* | | | | | Cor. for ′ of Alt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | | 0″ | 2″ | 4″ | 6″ | 8″ | |
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ | |
| 60 0 | 25 57 | 26 27 | 26 57 | 27 27 | 27 57 | 28 27 | 28 57 | 29 27 | 29 57 | 0 | 0 | 1 | 2 | 3 | 4 | |
| 10 | 25 49 | 26 19 | 26 49 | 27 19 | 27 48 | 28 18 | 28 48 | 29 18 | 29 48 | 10 | 5 | 6 | 7 | 8 | 9 | |
| 20 | 25 41 | 26 11 | 26 41 | 27 10 | 27 40 | 28 10 | 28 39 | 29 9 | 29 39 | 20 | 10 | 11 | 12 | 13 | 14 | |
| 30 | 25 33 | 26 3 | 26 32 | 27 2 | 27 32 | 28 1 | 28 31 | 29 0 | 29 30 | 30 | 15 | 16 | 17 | 18 | 19 | |
| 40 | 25 26 | 25 55 | 26 24 | 26 54 | 27 23 | 27 53 | 28 22 | 28 51 | 29 21 | 40 | 20 | 21 | 22 | 23 | 24 | |
| 50 | 25 18 | 25 47 | 26 16 | 26 45 | 27 15 | 27 44 | 28 13 | 28 42 | 29 12 | 50 | 25 | 26 | 27 | 28 | 29 | |
| 61 0 | 25 10 | 25 39 | 26 8 | 26 37 | 27 6 | 27 35 | 28 4 | 28 34 | 29 3 | 0 | 0 | 1 | 2 | 3 | 4 | |
| 10 | 25 2 | 25 31 | 26 0 | 26 29 | 26 58 | 27 27 | 27 56 | 28 25 | 28 54 | 10 | 5 | 6 | 7 | 8 | 9 | |
| 20 | 24 54 | 25 23 | 25 52 | 26 20 | 26 49 | 27 18 | 27 47 | 28 16 | 28 44 | 20 | 10 | 10 | 11 | 12 | 13 | |
| 30 | 24 46 | 25 15 | 25 43 | 26 12 | 26 41 | 27 9 | 27 38 | 28 7 | 28 35 | 30 | 14 | 15 | 16 | 17 | 18 | |
| 40 | 24 38 | 25 7 | 25 35 | 26 4 | 26 32 | 27 1 | 27 29 | 27 58 | 28 26 | 40 | 19 | 20 | 21 | 22 | 23 | |
| 50 | 24 30 | 24 59 | 25 27 | 25 55 | 26 24 | 26 52 | 27 20 | 27 49 | 28 17 | 50 | 24 | 25 | 26 | 27 | 28 | |
| 62 0 | 24 22 | 24 51 | 25 19 | 25 47 | 26 15 | 26 43 | 27 11 | 27 40 | 28 8 | 0 | 0 | 1 | 2 | 3 | 4 | |
| 10 | 24 14 | 24 42 | 25 10 | 25 38 | 26 6 | 26 35 | 27 3 | 27 31 | 27 59 | 10 | 5 | 6 | 6 | 7 | 8 | |
| 20 | 24 6 | 24 34 | 25 2 | 25 30 | 25 58 | 26 26 | 26 54 | 27 22 | 27 49 | 20 | 9 | 10 | 11 | 12 | 13 | |
| 30 | 23 58 | 24 26 | 24 54 | 25 22 | 25 49 | 26 17 | 26 45 | 27 12 | 27 40 | 30 | 14 | 15 | 16 | 17 | 18 | |
| 40 | 23 50 | 24 18 | 24 46 | 25 13 | 25 41 | 26 8 | 26 36 | 27 3 | 27 31 | 40 | 18 | 19 | 20 | 21 | 22 | |
| 50 | 23 42 | 24 10 | 24 37 | 25 5 | 25 32 | 25 59 | 26 27 | 26 54 | 27 22 | 50 | 23 | 24 | 25 | 26 | 27 | |
| 63 0 | 23 34 | 24 2 | 24 29 | 24 56 | 25 23 | 25 51 | 26 18 | 26 45 | 27 12 | 0 | 0 | 1 | 2 | 3 | 4 | |
| 10 | 23 26 | 23 53 | 24 21 | 24 48 | 25 15 | 25 42 | 26 9 | 26 36 | 27 3 | 10 | 4 | 5 | 6 | 7 | 8 | |
| 20 | 23 18 | 23 45 | 24 12 | 24 39 | 25 6 | 25 33 | 26 0 | 26 27 | 26 54 | 20 | 9 | 10 | 11 | 12 | 13 | |
| 30 | 23 10 | 23 37 | 24 4 | 24 31 | 24 57 | 25 24 | 25 51 | 26 18 | 26 44 | 30 | 13 | 14 | 15 | 16 | 17 | |
| 40 | 23 2 | 23 29 | 23 55 | 24 22 | 24 49 | 25 15 | 25 42 | 26 9 | 26 35 | 40 | 18 | 19 | 20 | 21 | 21 | |
| 50 | 22 54 | 23 21 | 23 47 | 24 14 | 24 40 | 25 6 | 25 33 | 25 59 | 26 26 | 50 | 22 | 23 | 24 | 25 | 26 | |
| 64 0 | 22 46 | 23 12 | 23 39 | 24 5 | 24 31 | 24 58 | 25 24 | 25 50 | 26 16 | 0 | 0 | 1 | 2 | 3 | 3 | |
| 10 | 22 38 | 23 4 | 23 30 | 23 56 | 24 22 | 24 49 | 25 15 | 25 41 | 26 7 | 10 | 4 | 5 | 6 | 7 | 8 | |
| 20 | 22 30 | 22 56 | 23 22 | 23 48 | 24 14 | 24 40 | 25 6 | 25 32 | 25 58 | 20 | 9 | 9 | 10 | 11 | 12 | |
| 30 | 22 22 | 22 47 | 23 13 | 23 39 | 24 5 | 24 31 | 24 57 | 25 23 | 25 48 | 30 | 13 | 14 | 15 | 15 | 16 | |
| 40 | 22 13 | 22 39 | 23 5 | 23 31 | 23 56 | 24 22 | 24 48 | 25 13 | 25 39 | 40 | 17 | 18 | 19 | 20 | 21 | |
| 50 | 22 5 | 22 31 | 22 56 | 23 22 | 23 47 | 24 13 | 24 38 | 25 4 | 25 29 | 50 | 22 | 22 | 23 | 24 | 25 | |
| 65 0 | 21 57 | 22 22 | 22 48 | 23 13 | 23 39 | 24 4 | 24 29 | 24 55 | 25 20 | 0 | 0 | 1 | 2 | 2 | 3 | |
| 10 | 21 49 | 22 14 | 22 39 | 23 5 | 23 30 | 23 55 | 24 20 | 24 45 | 25 11 | 10 | 4 | 5 | 6 | 7 | 7 | |
| 20 | 21 41 | 22 6 | 22 31 | 22 56 | 23 21 | 23 46 | 24 11 | 24 36 | 25 1 | 20 | 8 | 9 | 10 | 11 | 12 | |
| 30 | 21 33 | 21 57 | 22 22 | 22 47 | 23 12 | 23 37 | 24 2 | 24 27 | 24 52 | 30 | 12 | 13 | 14 | 15 | 16 | |
| 40 | 21 24 | 21 49 | 22 14 | 22 39 | 23 3 | 23 28 | 23 53 | 24 17 | 24 42 | 40 | 17 | 17 | 18 | 19 | 20 | |
| 50 | 21 16 | 21 41 | 22 5 | 22 30 | 22 54 | 23 19 | 23 44 | 24 8 | 24 33 | 50 | 21 | 21 | 22 | 23 | 24 | |
| 66 0 | 21 8 | 21 32 | 21 57 | 22 21 | 22 46 | 23 10 | 23 34 | 23 59 | 24 23 | 0 | 0 | 1 | 2 | 2 | 3 | |
| 10 | 21 0 | 21 24 | 21 49 | 22 12 | 22 37 | 23 1 | 23 25 | 23 49 | 24 14 | 10 | 4 | 5 | 6 | 6 | 7 | |
| 20 | 20 51 | 21 15 | 21 40 | 22 4 | 22 28 | 22 52 | 23 16 | 23 40 | 24 4 | 20 | 8 | 9 | 10 | 10 | 11 | |
| 30 | 20 43 | 21 7 | 21 31 | 21 55 | 22 19 | 22 43 | 23 7 | 23 31 | 23 55 | 30 | 12 | 13 | 14 | 14 | 15 | |
| 40 | 20 35 | 20 59 | 21 22 | 21 46 | 22 10 | 22 34 | 22 57 | 23 21 | 23 45 | 40 | 16 | 17 | 18 | 18 | 19 | |
| 50 | 20 27 | 20 50 | 21 14 | 21 37 | 22 1 | 22 25 | 22 48 | 23 12 | 23 35 | 50 | 20 | 21 | 21 | 22 | 23 | |
| 67 0 | 20 18 | 20 42 | 21 5 | 21 29 | 21 52 | 22 15 | 22 39 | 23 2 | 23 26 | 0 | 0 | 1 | 2 | 2 | 3 | |
| 10 | 20 10 | 20 33 | 20 56 | 21 20 | 21 43 | 22 6 | 22 30 | 22 53 | 23 16 | 10 | 4 | 5 | 5 | 6 | 7 | |
| 20 | 20 2 | 20 25 | 20 48 | 21 11 | 21 34 | 21 57 | 22 20 | 22 43 | 23 7 | 20 | 8 | 8 | 9 | 10 | 11 | |
| 30 | 19 53 | 20 16 | 20 39 | 21 2 | 21 25 | 21 48 | 22 11 | 22 34 | 22 57 | 30 | 11 | 12 | 13 | 14 | 14 | |
| 40 | 19 45 | 20 8 | 20 30 | 20 53 | 21 16 | 21 39 | 22 2 | 22 24 | 22 47 | 40 | 15 | 16 | 17 | 18 | 18 | |
| 50 | 19 36 | 19 59 | 20 22 | 20 44 | 21 7 | 21 30 | 21 52 | 22 15 | 22 38 | 50 | 19 | 20 | 21 | 21 | 22 | |
| 68 0 | 19 28 | 19 51 | 20 13 | 20 36 | 20 58 | 21 21 | 21 43 | 22 5 | 22 28 | 0 | 0 | 1 | 2 | 2 | 3 | |
| 10 | 19 20 | 19 42 | 20 4 | 20 27 | 20 49 | 21 11 | 21 34 | 21 56 | 22 18 | 10 | 4 | 4 | 5 | 6 | 7 | |
| 20 | 19 11 | 19 33 | 19 56 | 20 18 | 20 40 | 21 2 | 21 24 | 21 46 | 22 9 | 20 | 7 | 8 | 9 | 10 | 10 | |
| 30 | 19 3 | 19 25 | 19 47 | 20 9 | 20 31 | 20 53 | 21 15 | 21 37 | 21 59 | 30 | 11 | 12 | 12 | 13 | 14 | |
| 40 | 18 54 | 19 16 | 19 38 | 20 0 | 20 22 | 20 44 | 21 5 | 21 27 | 21 49 | 40 | 15 | 15 | 16 | 17 | 17 | |
| 50 | 18 46 | 19 8 | 19 29 | 19 51 | 20 13 | 20 34 | 20 56 | 21 18 | 21 39 | 50 | 18 | 19 | 20 | 20 | 21 | |
| 69 0 | 18 38 | 18 59 | 19 21 | 19 42 | 20 4 | 20 25 | 20 47 | 21 8 | 21 30 | 0 | 0 | 1 | 1 | 2 | 3 | |
| 10 | 18 29 | 18 50 | 19 12 | 19 33 | 19 54 | 20 16 | 20 37 | 20 59 | 21 20 | 10 | 4 | 4 | 5 | 6 | 6 | |
| 20 | 18 21 | 18 42 | 19 3 | 19 24 | 19 45 | 20 7 | 20 28 | 20 49 | 21 10 | 20 | 7 | 8 | 8 | 9 | 10 | |
| 30 | 18 12 | 18 33 | 18 54 | 19 15 | 19 36 | 19 57 | 20 18 | 20 39 | 21 0 | 30 | 11 | 11 | 12 | 13 | 13 | |
| 40 | 18 4 | 18 25 | 18 45 | 19 6 | 19 27 | 19 48 | 20 9 | 20 30 | 20 51 | 40 | 14 | 15 | 15 | 16 | 17 | |
| 50 | 17 55 | 18 16 | 18 37 | 18 57 | 19 18 | 19 39 | 19 59 | 20 20 | 20 41 | 50 | 18 | 18 | 19 | 20 | 20 | |

| *sub* | |
|---|---|
| ′ | ″ |
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 4 |
| 6 | 5 |
| 7 | 6 |
| 8 | 7 |
| 9 | 8 |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | ″ of Par. | Corr. for ″ of Par. *add.* 0″ | 2″ | 4″ | 6″ | 8″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ |
| 70 0 | 17 47 | 18 7 | 18 28 | 18 48 | 19 9 | 19 29 | 19 50 | 20 10 | 20 31 | 0 | 0 | 1 | 1 | 2 | 3 |
| 10 | 17 38 | 17 59 | 18 19 | 18 39 | 19 0 | 19 20 | 19 40 | 20 1 | 20 21 | 10 | 3 | 4 | 5 | 5 | 6 |
| 20 | 17 30 | 17 50 | 18 10 | 18 30 | 18 51 | 19 11 | 19 31 | 19 51 | 20 11 | 20 | 7 | 7 | 8 | 9 | 9 |
| 30 | 17 21 | 17 41 | 18 1 | 18 21 | 18 41 | 19 1 | 19 21 | 19 41 | 20 1 | 30 | 10 | 11 | 11 | 12 | 13 |
| 40 | 17 13 | 17 33 | 17 52 | 18 12 | 18 32 | 18 52 | 19 12 | 19 32 | 19 52 | 40 | 13 | 14 | 15 | 15 | 16 |
| 50 | 17 4 | 17 24 | 17 44 | 18 3 | 18 23 | 18 43 | 19 2 | 19 22 | 19 42 | 50 | 17 | 17 | 18 | 19 | 19 |
| 71 0 | 16 56 | 17 15 | 17 35 | 17 54 | 18 14 | 18 33 | 18 53 | 19 12 | 19 32 | 0 | 0 | 1 | 1 | 2 | 3 |
| 10 | 16 47 | 17 6 | 17 26 | 17 45 | 18 4 | 18 24 | 18 43 | 19 3 | 19 22 | 10 | 3 | 4 | 4 | 5 | 6 |
| 20 | 16 38 | 16 58 | 17 17 | 17 36 | 17 55 | 18 15 | 18 34 | 18 53 | 19 12 | 20 | 6 | 7 | 8 | 8 | 9 |
| 30 | 16 30 | 16 49 | 17 8 | 17 27 | 17 46 | 18 5 | 18 24 | 18 43 | 19 2 | 30 | 10 | 10 | 11 | 11 | 12 |
| 40 | 16 21 | 16 40 | 16 59 | 17 18 | 17 37 | 17 56 | 18 15 | 18 33 | 18 52 | 40 | 13 | 13 | 14 | 15 | 15 |
| 50 | 16 13 | 16 31 | 16 50 | 17 9 | 17 28 | 17 46 | 18 5 | 18 24 | 18 42 | 50 | 16 | 16 | 17 | 18 | 18 |
| 72 0 | 16 4 | 16 23 | 16 41 | 17 0 | 17 18 | 17 37 | 17 55 | 18 14 | 18 32 | 0 | 0 | 1 | 1 | 2 | 2 |
| 10 | 15 55 | 16 14 | 16 32 | 16 51 | 17 9 | 17 27 | 17 46 | 18 4 | 18 22 | 10 | 3 | 4 | 4 | 5 | 5 |
| 20 | 15 47 | 16 5 | 16 23 | 16 41 | 17 0 | 17 18 | 17 36 | 17 54 | 18 13 | 20 | 6 | 7 | 7 | 8 | 8 |
| 30 | 15 38 | 15 56 | 16 14 | 16 32 | 16 50 | 17 8 | 17 26 | 17 44 | 18 3 | 30 | 9 | 10 | 10 | 11 | 11 |
| 40 | 15 29 | 15 47 | 16 5 | 16 23 | 16 41 | 16 59 | 17 17 | 17 35 | 17 53 | 40 | 12 | 13 | 13 | 14 | 14 |
| 50 | 15 21 | 15 39 | 15 56 | 16 14 | 16 32 | 16 49 | 17 7 | 17 25 | 17 43 | 50 | 15 | 16 | 16 | 17 | 17 |
| 73 0 | 15 12 | 15 30 | 15 47 | 16 5 | 16 22 | 16 40 | 16 57 | 17 15 | 17 33 | 0 | 0 | 1 | 1 | 2 | 2 |
| 10 | 15 3 | 15 21 | 15 38 | 15 56 | 16 13 | 16 30 | 16 48 | 17 5 | 17 23 | 10 | 3 | 3 | 4 | 5 | 5 |
| 20 | 14 55 | 15 12 | 15 29 | 15 46 | 16 4 | 16 21 | 16 38 | 16 55 | 17 13 | 20 | 6 | 6 | 7 | 7 | 8 |
| 30 | 14 46 | 15 3 | 15 20 | 15 37 | 15 54 | 16 11 | 16 28 | 16 45 | 17 3 | 30 | 9 | 9 | 10 | 10 | 11 |
| 40 | 14 37 | 14 54 | 15 11 | 15 28 | 15 45 | 16 2 | 16 19 | 16 36 | 16 52 | 40 | 11 | 12 | 12 | 13 | 14 |
| 50 | 14 29 | 14 45 | 15 2 | 15 19 | 15 36 | 15 52 | 16 9 | 16 26 | 16 42 | 50 | 14 | 15 | 15 | 16 | 16 |
| 74 0 | 14 20 | 14 37 | 14 53 | 15 10 | 15 26 | 15 43 | 15 59 | 16 16 | 16 32 | 0 | 0 | 1 | 1 | 2 | 2 |
| 10 | 14 11 | 14 28 | 14 44 | 15 0 | 15 17 | 15 33 | 15 50 | 16 6 | 16 22 | 10 | 3 | 3 | 4 | 4 | 5 |
| 20 | 14 3 | 14 19 | 14 35 | 14 51 | 15 7 | 15 24 | 15 40 | 15 56 | 16 12 | 20 | 5 | 6 | 6 | 7 | 7 |
| 30 | 13 54 | 14 10 | 14 26 | 14 42 | 14 58 | 15 14 | 15 30 | 15 46 | 16 2 | 30 | 8 | 9 | 9 | 10 | 10 |
| 40 | 13 45 | 14 1 | 14 17 | 14 33 | 14 49 | 15 4 | 15 20 | 15 36 | 15 52 | 40 | 11 | 11 | 12 | 12 | 13 |
| 50 | 13 36 | 13 52 | 14 8 | 14 24 | 14 39 | 14 55 | 15 11 | 15 26 | 15 42 | 50 | 13 | 14 | 14 | 15 | 15 |
| 75 0 | 13 28 | 13 43 | 13 59 | 14 14 | 14 30 | 14 45 | 15 1 | 15 16 | 15 32 | 0 | 0 | 1 | 1 | 2 | 2 |
| 10 | 13 19 | 13 34 | 13 50 | 14 5 | 14 20 | 14 36 | 14 51 | 15 6 | 15 22 | 10 | 3 | 3 | 4 | 4 | 5 |
| 20 | 13 10 | 13 25 | 13 41 | 13 56 | 14 11 | 14 26 | 14 41 | 14 56 | 15 12 | 20 | 5 | 6 | 6 | 7 | 7 |
| 30 | 13 1 | 13 16 | 13 31 | 13 46 | 14 1 | 14 16 | 14 32 | 14 47 | 15 2 | 30 | 8 | 8 | 9 | 9 | 10 |
| 40 | 12 53 | 13 7 | 13 22 | 13 37 | 13 52 | 14 7 | 14 22 | 14 37 | 14 51 | 40 | 10 | 11 | 11 | 12 | 12 |
| 50 | 12 44 | 12 58 | 13 13 | 13 28 | 13 43 | 13 57 | 14 12 | 14 27 | 14 41 | 50 | 13 | 13 | 14 | 14 | 15 |
| 76 0 | 12 35 | 12 50 | 13 4 | 13 19 | 13 33 | 13 48 | 14 2 | 14 17 | 14 31 | 0 | 0 | 0 | 1 | 1 | 2 |
| 10 | 12 26 | 12 41 | 12 55 | 13 9 | 13 24 | 13 38 | 13 52 | 14 7 | 14 21 | 10 | 2 | 3 | 3 | 4 | 4 |
| 20 | 12 17 | 12 32 | 12 46 | 13 0 | 13 14 | 13 28 | 13 42 | 13 57 | 14 11 | 20 | 5 | 5 | 6 | 6 | 7 |
| 30 | 12 9 | 12 23 | 12 37 | 12 51 | 13 5 | 13 19 | 13 33 | 13 47 | 14 1 | 30 | 7 | 7 | 8 | 8 | 9 |
| 40 | 12 0 | 12 14 | 12 27 | 12 41 | 12 55 | 13 9 | 13 23 | 13 37 | 13 50 | 40 | 9 | 10 | 10 | 11 | 11 |
| 50 | 11 51 | 12 5 | 12 18 | 12 32 | 12 46 | 12 59 | 13 13 | 13 27 | 13 40 | 50 | 12 | 12 | 13 | 13 | 14 |
| 77 0 | 11 42 | 11 56 | 12 9 | 12 23 | 12 36 | 12 50 | 13 3 | 13 17 | 13 30 | 0 | 0 | 0 | 1 | 1 | 2 |
| 10 | 11 33 | 11 47 | 12 0 | 12 13 | 12 27 | 12 40 | 12 53 | 13 6 | 13 20 | 10 | 2 | 3 | 3 | 4 | 4 |
| 20 | 11 24 | 11 37 | 11 51 | 12 4 | 12 17 | 12 30 | 12 43 | 12 56 | 13 10 | 20 | 4 | 5 | 5 | 6 | 6 |
| 30 | 11 15 | 11 28 | 11 41 | 11 54 | 12 7 | 12 20 | 12 33 | 12 46 | 12 59 | 30 | 7 | 7 | 7 | 8 | 8 |
| 40 | 11 7 | 11 19 | 11 32 | 11 45 | 11 58 | 12 11 | 12 24 | 12 36 | 12 49 | 40 | 9 | 9 | 10 | 10 | 10 |
| 50 | 10 58 | 11 10 | 11 23 | 11 36 | 11 48 | 12 1 | 12 14 | 12 26 | 12 39 | 50 | 11 | 11 | 12 | 12 | 13 |
| 78 0 | 10 49 | 11 1 | 11 14 | 11 26 | 11 39 | 11 51 | 12 4 | 12 16 | 12 29 | 0 | 0 | 0 | 1 | 1 | 2 |
| 10 | 10 40 | 10 52 | 11 5 | 11 17 | 11 29 | 11 42 | 11 54 | 12 6 | 12 19 | 10 | 2 | 2 | 3 | 3 | 4 |
| 20 | 10 31 | 10 43 | 10 55 | 11 8 | 11 20 | 11 32 | 11 44 | 11 56 | 12 8 | 20 | 4 | 4 | 5 | 5 | 6 |
| 30 | 10 22 | 10 34 | 10 46 | 10 58 | 11 10 | 11 22 | 11 34 | 11 46 | 11 58 | 30 | 6 | 6 | 7 | 7 | 8 |
| 40 | 10 13 | 10 25 | 10 37 | 10 49 | 11 1 | 11 12 | 11 24 | 11 36 | 11 48 | 40 | 8 | 8 | 9 | 8 | 10 |
| 50 | 10 5 | 10 16 | 10 28 | 10 39 | 10 51 | 11 3 | 11 14 | 11 26 | 11 38 | 50 | 10 | 10 | 11 | 11 | 12 |
| 79 0 | 9 56 | 10 7 | 10 19 | 10 30 | 10 41 | 10 53 | 11 4 | 11 16 | 11 27 | 0 | 0 | 0 | 1 | 1 | 1 |
| 10 | 9 47 | 9 58 | 10 9 | 10 21 | 10 32 | 10 43 | 10 54 | 11 6 | 11 17 | 10 | 2 | 2 | 3 | 3 | 3 |
| 20 | 9 38 | 9 49 | 10 0 | 10 11 | 10 22 | 10 33 | 10 44 | 10 56 | 11 7 | 20 | 4 | 4 | 4 | 5 | 5 |
| 30 | 9 29 | 9 40 | 9 51 | 10 2 | 10 13 | 10 24 | 10 34 | 10 45 | 10 56 | 30 | 5 | 6 | 6 | 7 | 7 |
| 40 | 9 20 | 9 31 | 9 41 | 9 52 | 10 3 | 10 14 | 10 25 | 10 35 | 10 46 | 40 | 7 | 8 | 8 | 8 | 9 |
| 50 | 9 11 | 9 22 | 9 32 | 9 43 | 9 53 | 10 4 | 10 15 | 10 25 | 10 36 | 50 | 9 | 9 | 10 | 10 | 11 |

| Cor. for ′ of Alt. | |
|---|---|
| *sub.* | |
| ′ | ″ |
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |

## CORRECTION OF THE MOON'S APPARENT ALTITUDE.

(Barometer, 30 inches. Fahrenheit's Thermometer, 50°.)

| ☽ App. Alt. | Horizontal Parallax. 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ | ″ of Par. | Corr. for ″ of Par. *add.* 0″ | 2″ | 4″ | 6″ | 8″ | Cor. for ′ of Alt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° ′ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | ′ ″ | ″ | ″ | ″ | ″ | ″ | ″ | |
| 80 0 | 9 2 | 9 12 | 9 23 | 9 33 | 9 44 | 9 54 | 10 5 | 10 15 | 10 25 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 10 | 8 53 | 9 3 | 9 14 | 9 24 | 9 34 | 9 44 | 9 55 | 10 5 | 10 15 | 10 | 2 | 2 | 2 | 3 | 3 | |
| 20 | 8 44 | 8 54 | 9 4 | 9 14 | 9 24 | 9 35 | 9 45 | 9 55 | 10 5 | 20 | 3 | 4 | 4 | 4 | 5 | |
| 30 | 8 35 | 8 45 | 8 55 | 9 5 | 9 15 | 9 25 | 9 35 | 9 45 | 9 54 | 30 | 5 | 5 | 6 | 6 | 6 | |
| 40 | 8 26 | 8 36 | 8 46 | 8 55 | 9 5 | 9 15 | 9 25 | 9 34 | 9 44 | 40 | 7 | 7 | 7 | 8 | 8 | |
| 50 | 8 17 | 8 27 | 8 36 | 8 46 | 8 56 | 9 5 | 9 15 | 9 24 | 9 34 | 50 | 8 | 9 | 9 | 9 | 10 | |
| 81 0 | 8 8 | 8 18 | 8 27 | 8 37 | 8 46 | 8 55 | 9 5 | 9 14 | 9 24 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 10 | 7 59 | 8 9 | 8 18 | 8 27 | 8 36 | 8 45 | 8 55 | 9 4 | 9 13 | 10 | 1 | 2 | 2 | 2 | 3 | |
| 20 | 7 50 | 7 59 | 8 9 | 8 18 | 8 27 | 8 36 | 8 45 | 8 54 | 9 3 | 20 | 3 | 3 | 4 | 4 | 4 | |
| 30 | 7 41 | 7 50 | 7 59 | 8 8 | 8 17 | 8 26 | 8 35 | 8 44 | 8 52 | 30 | 4 | 5 | 5 | 5 | 6 | |
| 40 | 7 32 | 7 41 | 7 50 | 7 59 | 8 7 | 8 16 | 8 25 | 8 33 | 8 42 | 40 | 6 | 6 | 7 | 7 | 7 | |
| 50 | 7 24 | 7 32 | 7 41 | 7 49 | 7 58 | 8 6 | 8 15 | 8 23 | 8 32 | 50 | 7 | 8 | 8 | 8 | 9 | |
| 82 0 | 7 14 | 7 23 | 7 31 | 7 40 | 7 48 | 7 56 | 8 5 | 8 13 | 8 21 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 10 | 7 5 | 7 14 | 7 22 | 7 30 | 7 38 | 7 46 | 7 55 | 8 3 | 8 11 | 10 | 1 | 2 | 2 | 2 | 2 | |
| 20 | 6 57 | 7 5 | 7 13 | 7 21 | 7 29 | 7 37 | 7 45 | 7 53 | 8 1 | 20 | 3 | 3 | 3 | 3 | 4 | |
| 30 | 6 48 | 6 55 | 7 3 | 7 11 | 7 19 | 7 27 | 7 34 | 7 42 | 7 50 | 30 | 4 | 4 | 4 | 5 | 5 | |
| 40 | 6 38 | 6 46 | 6 54 | 7 1 | 7 9 | 7 17 | 7 24 | 7 32 | 7 40 | 40 | 5 | 5 | 6 | 6 | 6 | |
| 50 | 6 29 | 6 37 | 6 44 | 6 52 | 6 59 | 7 7 | 7 14 | 7 22 | 7 29 | 50 | 6 | 7 | 7 | 7 | 8 | |
| 83 0 | 6 20 | 6 28 | 6 35 | 6 42 | 6 50 | 6 57 | 7 4 | 7 12 | 7 19 | 0 | 0 | 0 | 0 | 1 | 1 | |
| 10 | 6 11 | 6 19 | 6 26 | 6 33 | 6 40 | 6 47 | 6 54 | 7 1 | 7 9 | 10 | 1 | 1 | 2 | 2 | 2 | |
| 20 | 6 2 | 6 9 | 6 16 | 6 23 | 6 30 | 6 37 | 6 44 | 6 51 | 6 58 | 20 | 2 | 2 | 3 | 3 | 3 | |
| 30 | 5 53 | 6 0 | 6 7 | 6 14 | 6 21 | 6 27 | 6 34 | 6 41 | 6 48 | 30 | 3 | 4 | 4 | 4 | 4 | |
| 40 | 5 44 | 5 51 | 5 58 | 6 4 | 6 11 | 6 18 | 6 24 | 6 31 | 6 37 | 40 | 5 | 5 | 5 | 5 | 5 | |
| 50 | 5 35 | 5 42 | 5 48 | 5 55 | 6 1 | 6 8 | 6 14 | 6 21 | 6 27 | 50 | 6 | 6 | 6 | 6 | 7 | |
| 84 0 | 5 26 | 5 33 | 5 39 | 5 45 | 5 51 | 5 58 | 6 4 | 6 10 | 6 17 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 10 | 5 17 | 5 23 | 5 30 | 5 36 | 5 42 | 5 48 | 5 54 | 6 0 | 6 6 | 10 | 1 | 1 | 1 | 1 | 2 | |
| 20 | 5 8 | 5 14 | 5 20 | 5 26 | 5 32 | 5 38 | 5 44 | 5 50 | 5 56 | 20 | 2 | 2 | 2 | 2 | 3 | |
| 30 | 4 59 | 5 5 | 5 11 | 5 17 | 5 22 | 5 28 | 5 34 | 5 40 | 5 45 | 30 | 3 | 3 | 3 | 3 | 4 | |
| 40 | 4 50 | 4 56 | 5 1 | 5 7 | 5 13 | 5 18 | 5 24 | 5 29 | 5 35 | 40 | 4 | 4 | 4 | 4 | 5 | |
| 50 | 4 41 | 4 47 | 4 52 | 4 57 | 5 3 | 5 8 | 5 14 | 5 19 | 5 24 | 50 | 5 | 5 | 5 | 5 | 6 | |
| 85 0 | 4 32 | 4 37 | 4 43 | 4 48 | 4 53 | 4 58 | 5 4 | 5 9 | 5 14 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 10 | 4 23 | 4 28 | 4 33 | 4 38 | 4 43 | 4 48 | 4 53 | 4 58 | 5 4 | 10 | 1 | 1 | 1 | 1 | 1 | |
| 20 | 4 14 | 4 19 | 4 24 | 4 29 | 4 34 | 4 38 | 4 43 | 4 48 | 4 53 | 20 | 2 | 2 | 2 | 2 | 2 | |
| 30 | 4 5 | 4 10 | 4 14 | 4 19 | 4 24 | 4 28 | 4 33 | 4 38 | 4 43 | 30 | 2 | 2 | 3 | 3 | 3 | |
| 40 | 3 56 | 4 0 | 4 5 | 4 10 | 4 14 | 4 19 | 4 23 | 4 28 | 4 32 | 40 | 3 | 3 | 3 | 4 | 4 | |
| 50 | 3 47 | 3 51 | 3 56 | 4 0 | 4 4 | 4 9 | 4 13 | 4 17 | 4 22 | 50 | 4 | 4 | 4 | 4 | 5 | |
| 86 0 | 3 38 | 3 42 | 3 46 | 3 50 | 3 55 | 3 59 | 4 3 | 4 7 | 4 11 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 10 | 3 29 | 3 33 | 3 37 | 3 41 | 3 45 | 3 49 | 3 53 | 3 57 | 4 1 | 10 | 1 | 1 | 1 | 1 | 1 | |
| 20 | 3 20 | 3 23 | 3 27 | 3 31 | 3 35 | 3 39 | 3 43 | 3 47 | 3 50 | 20 | 1 | 1 | 1 | 2 | 2 | |
| 30 | 3 11 | 3 14 | 3 18 | 3 22 | 3 25 | 3 29 | 3 33 | 3 36 | 3 40 | 30 | 2 | 2 | 2 | 2 | 2 | |
| 40 | 3 2 | 3 5 | 3 9 | 3 12 | 3 15 | 3 19 | 3 22 | 3 26 | 3 29 | 40 | 2 | 3 | 3 | 3 | 3 | |
| 50 | 2 53 | 2 56 | 2 59 | 3 2 | 3 6 | 3 9 | 3 12 | 3 16 | 3 19 | 50 | 3 | 3 | 3 | 3 | 4 | |
| 87 0 | 2 43 | 2 47 | 2 50 | 2 53 | 2 56 | 2 59 | 3 2 | 3 5 | 3 8 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 10 | 2 34 | 2 37 | 2 40 | 2 43 | 2 46 | 2 49 | 2 52 | 2 55 | 2 58 | 10 | 0 | 1 | 1 | 1 | 1 | |
| 20 | 2 25 | 2 28 | 2 31 | 2 34 | 2 36 | 2 39 | 2 42 | 2 45 | 2 48 | 20 | 1 | 1 | 1 | 1 | 1 | |
| 30 | 2 16 | 2 19 | 2 21 | 2 24 | 2 27 | 2 29 | 2 32 | 2 35 | 2 37 | 30 | 1 | 1 | 1 | 2 | 2 | |
| 40 | 2 7 | 2 10 | 2 12 | 2 14 | 2 17 | 2 19 | 2 22 | 2 24 | 2 27 | 40 | 2 | 2 | 2 | 2 | 2 | |
| 50 | 1 58 | 2 0 | 2 3 | 2 5 | 2 7 | 2 9 | 2 12 | 2 14 | 2 16 | 50 | 2 | 2 | 2 | 2 | 3 | |
| 88 0 | 1 49 | 1 51 | 1 53 | 1 55 | 1 57 | 1 59 | 2 2 | 2 4 | 2 6 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 10 | 1 40 | 1 42 | 1 44 | 1 46 | 1 48 | 1 50 | 1 51 | 1 53 | 1 55 | 10 | 0 | 0 | 0 | 0 | 0 | |
| 20 | 1 31 | 1 33 | 1 34 | 1 36 | 1 38 | 1 40 | 1 41 | 1 43 | 1 45 | 20 | 1 | 1 | 1 | 1 | 1 | |
| 30 | 1 22 | 1 23 | 1 25 | 1 26 | 1 28 | 1 30 | 1 31 | 1 33 | 1 34 | 30 | 1 | 1 | 1 | 1 | 1 | |
| 40 | 1 13 | 1 14 | 1 15 | 1 17 | 1 18 | 1 20 | 1 21 | 1 22 | 1 24 | 40 | 1 | 1 | 1 | 1 | 1 | |
| 50 | 1 4 | 1 5 | 1 6 | 1 7 | 1 9 | 1 10 | 1 11 | 1 12 | 1 13 | 50 | 1 | 1 | 1 | 1 | 2 | |
| 89 0 | 0 54 | 0 56 | 0 57 | 0 58 | 0 59 | 1 0 | 1 1 | 1 2 | 1 3 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 10 | 0 45 | 0 46 | 0 47 | 0 48 | 0 49 | 0 50 | 0 51 | 0 52 | 0 52 | 10 | 0 | 0 | 0 | 0 | 0 | |
| 20 | 0 36 | 0 37 | 0 38 | 0 38 | 0 39 | 0 40 | 0 41 | 0 41 | 0 42 | 20 | 0 | 0 | 0 | 0 | 0 | |
| 30 | 0 27 | 0 28 | 0 28 | 0 29 | 0 29 | 0 30 | 0 30 | 0 31 | 0 31 | 30 | 0 | 0 | 0 | 0 | 0 | |
| 40 | 0 18 | 0 19 | 0 19 | 0 19 | 0 20 | 0 20 | 0 20 | 0 21 | 0 21 | 40 | 0 | 0 | 0 | 0 | 0 | |
| 50 | 0 9 | 0 9 | 0 9 | 0 10 | 0 10 | 0 10 | 0 10 | 0 10 | 0 10 | 50 | 1 | 1 | 1 | 1 | 1 | |

*sub.*

| ′ | ″ |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |

## TABLE VIII.

### THE SUN'S PARALLAX IN ALTITUDE.

| Month. | Altitude. 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | Month. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. 1. | 8″·7 | 8″·6 | 8″·2 | 7″·6 | 6″·7 | 5″·6 | 4″·4 | 3″·0 | 1″·5 | 0″ | Dec. 1. |
| Feb 1. | 8 7 | 8 6 | 8 2 | 7 6 | 6 6 | 5 6 | 4 3 | 3 0 | 1·5 | 0 | Nov. 1. |
| Mar. 1. | 8 6 | 8 5 | 8 1 | 7 5 | 6 6 | 5 5 | 4 3 | 3 0 | 1·5 | 0 | Oct. 1. |
| Apr. 1. | 8·5 | 8 4 | 8 0 | 7 4 | 6 5 | 5 5 | 4 3 | 3 0 | 1·5 | 0 | Sept. 1. |
| May 1. | 8 4 | 8 3 | 8 0 | 7 3 | 6 5 | 5 4 | 4 2 | 2·9 | 1·5 | 0 | Aug. 1. |
| June 1. | 8·4 | 8·3 | 8·0 | 7 3 | 6 4 | 5 4 | 4 2 | 2·9 | 1·5 | 0 | July 1. |

## TABLE IX.

### DIP OF THE SHORE HORIZON.

| | Height of the eye in feet. 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| ½ | 6′ | 12′ | 17′ | 23′ | 28′ | 34′ | 40′ | 45′ |
| 1 | 3 | 6 | 9 | 12 | 15 | 17 | 20 | 23 |
| 1½ | 3 | 5 | 7 | 10 | 12 | 14 | 16 | 19 |
| 2 | 2 | 4 | 5 | 7 | 8 | 9 | 11 | 12 |
| 2½ | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 |
| 3 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 3½ | | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 4 | | 3 | 4 | 5 | 5 | 6 | 7 | 7 |
| 5 | | | 4 | 4 | 5 | 6 | 6 | 7 |
| 6 | | | | | 5 | 5 | 6 | 6 |

## TABLE X.

### AUGMENTATION
OF THE MOON'S SEMIDIAMETER.

| App. Alt. | 14′ | 15′ | | 16′ | | 17′ |
|---|---|---|---|---|---|---|
| | 30″ | 0″ | 30″ | 0″ | 30″ | 0″ |
| ° | | | | | | |
| 0 | 0″·1 | 0″·1 | 0″·1 | 0″·1 | 0″·1 | 0″·1 |
| 2 | 0·6 | 0 6 | 0·7 | 0·7 | 0 8 | 0·8 |
| 4 | 1·0 | 1·1 | 1·2 | 1·3 | 1 4 | 1·5 |
| 6 | 1·5 | 1·6 | 1·7 | 1·9 | 2 0 | 2·1 |
| 8 | 2·0 | 2·1 | 2·2 | 2·4 | 2 5 | 2·7 |
| 10 | 2·4 | 2·7 | 2·8 | 3 0 | 3 2 | 3 3 |
| 12 | 2·9 | 3·2 | 3 3 | 3 5 | 3 7 | 4 0 |
| 14 | 3 4 | 3·6 | 3 8 | 4·1 | 4 4 | 4 6 |
| 16 | 3 9 | 4·1 | 4 4 | 4 7 | 5 0 | 5·2 |
| 18 | 4 3 | 4 6 | 4 9 | 5 2 | 5 5 | 5·9 |
| 21 | 4 9 | 5·3 | 5 7 | 6 0 | 6 4 | 6 7 |
| 24 | 5 6 | 6 0 | 6 4 | 6 8 | 7 2 | 7·7 |
| 27 | 6·2 | 6·7 | 7·2 | 7 6 | 8 1 | 8·6 |
| 30 | 6 9 | 7·4 | 7 9 | 8·4 | 8 9 | 9·4 |
| 33 | 7·5 | 8·0 | 8 6 | 9·1 | 9 6 | 10·3 |
| 36 | 8·0 | 8·6 | 9 2 | 9·8 | 10 4 | 11·1 |
| 39 | 8·6 | 9·2 | 9 9 | 10·5 | 11·1 | 11·8 |
| 42 | 9·1 | 9·8 | 10·4 | 11·2 | 11 8 | 12·6 |
| 45 | 9 7 | 10·3 | 11·0 | 11·8 | 12·5 | 13·3 |
| 48 | 10·2 | 10·9 | 11·6 | 12·4 | 13 1 | 14 0 |
| 51 | 10·6 | 11·3 | 12·1 | 12·9 | 13 7 | 14·6 |
| 54 | 11·1 | 11·8 | 12·6 | 13 5 | 14 3 | 15 2 |
| 57 | 11·5 | 12·3 | 13·1 | 14 0 | 14 8 | 15·7 |
| 63 | 12·2 | 13·0 | 13·9 | 14·8 | 15 7 | 16·7 |
| 70 | 12·7 | 13·7 | 14·7 | 15·7 | 16 6 | 17·6 |
| 78 | 13 3 | 14·3 | 15·3 | 16 3 | 17 3 | 18·4 |
| 90 | 13·5 | 14·6 | 15·6 | 16·7 | 17 6 | 18·6 |

## TABLE XI.

### CORRECTION
OF THE LUNAR DISTANCE FOR THE CONTRACTION OF THE VERTICAL SEMIDIAMETER.

| Alt. | Angle between the Lunar Distance and the Plumb-line. 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|
| 3° | 51″ | 49″ | 45″ | 38″ | 30″ | 21″ | 13″ | 6″ | 1″ | 0″ |
| 4 | 36 | 35 | 32 | 27 | 21 | 15 | 9 | 4 | 1 | 0 |
| 5 | 26 | 24 | 22 | 19 | 15 | 10 | 6 | 3 | 1 | 0 |
| 6 | 20 | 19 | 18 | 15 | 12 | 8 | 5 | 2 | 0 | 0 |
| 7 | 16 | 16 | 14 | 12 | 9 | 6 | 4 | 2 | 0 | 0 |
| 8 | 11 | 11 | 10 | 9 | 7 | 4 | 3 | 1 | 0 | 0 |
| 9 | 10 | 9 | 9 | 7 | 6 | 4 | 2 | 1 | 0 | 0 |
| 10 | 9 | 8 | 7 | 6 | 5 | 3 | 2 | 1 | 0 | 0 |
| 12 | 5 | 5 | 4 | 4 | 3 | 2 | 1 | 1 | 0 | 0 |
| 15 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 |
| 20 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 30 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

For the *nearest* Limb *sub.*; for the *farthest* Limb *add.*

## TABLE XII.

**CORRECTION**
FOR REDUCING THE TRUE ALTITUDE OF THE SUN OR A STAR TO THE APPARENT ALTITUDE.

| Alt. | Corr. | Alt. | Corr. |
|---|---|---|---|
| | *sub.* | | *sub.* |
| 5° 0′ | 0′ 16″ | 7° 30′ | 0′ 6″ |
| 5 20 | 0 15 | 8 0 | 0 5 |
| 5 40 | 0 12 | 9 0 | 0 3 |
| 6 0 | 0 11 | 10 0 | 0 2 |
| 6 20 | 0 9 | 15 0 | 0 1 |
| 6 40 | 0 8 | 25 0 | 0 0 |
| 7 0 | 0 7 | | |

## TABLE XIII.

**CORRECTION**
FOR REDUCING THE TRUE ALTITUDE OF THE MOON TO THE APPARENT ALTITUDE.

| Alt. | Horizontal Parallax. | | |
|---|---|---|---|
| | 54′ | 58′ | 61′ |
| | *add.* | *add.* | *add.* |
| 5° 0′ | 1′ 14″ | 1′ 22″ | 1′ 28″ |
| 5 10 | 1 10 | 1 18 | 1 23 |
| 5 20 | 1 7 | 1 15 | 1 19 |
| 5 30 | 1 5 | 1 11 | 1 16 |
| 5 40 | 1 3 | 1 8 | 1 13 |
| 5 50 | 1 0 | 1 5 | 1 10 |
| 6 0 | 0 57 | 1 3 | 1 7 |
| 6 20 | 0 52 | 0 57 | 1 2 |
| 6 40 | 0 47 | 0 51 | 0 54 |
| 7 0 | 0 45 | 0 47 | 0 51 |
| 7 20 | 0 41 | 0 44 | 0 47 |
| 7 40 | 0 37 | 0 40 | 0 42 |
| 8 0 | 0 34 | 0 36 | 0 38 |
| 8 30 | 0 30 | 0 32 | 0 33 |
| 9 0 | 0 26 | 0 28 | 0 29 |
| 9 30 | 0 22 | 0 24 | 0 25 |
| 10 0 | 0 19 | 0 20 | 0 20 |
| 10 30 | 0 16 | 0 17 | 0 18 |
| 11 0 | 0 14 | 0 14 | 0 14 |
| 11 30 | 0 12 | 0 12 | 0 11 |
| 12 0 | 0 9 | 0 9 | 0 9 |
| 13 0 | 0 6 | 0 6 | 0 7 |
| 14 0 | 0 4 | 0 3 | 0 2 |
| 15 0 | 0 0 | 0 0 | 0 0 |
| | *sub.* | *sub.* | *sub.* |
| 16 0 | 0 0 | 0 2 | 0 3 |
| 17 0 | 0 3 | 0 4 | 0 6 |
| 18 0 | 0 5 | 0 6 | 0 8 |
| 20 0 | 0 8 | 0 9 | 0 11 |
| 22 0 | 0 10 | 0 14 | 0 15 |
| 24 0 | 0 13 | 0 15 | 0 18 |
| 26 0 | 0 15 | 0 17 | 0 19 |
| 28 0 | 0 17 | 0 20 | 0 21 |
| 30 0 | 0 18 | 0 22 | 0 24 |
| 34 0 | 0 20 | 0 24 | 0 27 |
| 40 0 | 0 23 | 0 27 | 0 30 |
| 50 0 | 0 24 | 0 27 | 0 30 |
| 60 0 | 0 21 | 0 24 | 0 27 |
| 65 0 | 0 18 | 0 21 | 0 23 |
| 70 0 | 0 16 | 0 18 | 0 20 |
| 74 0 | 0 13 | 0 16 | 0 18 |
| 78 0 | 0 10 | 0 12 | 0 13 |
| 80 0 | 0 8 | 0 10 | 0 11 |
| 82 0 | 0 6 | 0 8 | 0 9 |
| 84 0 | 0 5 | 0 6 | 0 6 |
| 86 0 | 0 4 | 0 4 | 0 4 |
| 88 0 | 0 2 | 0 2 | 0 2 |
| 90 0 | 0 0 | 0 0 | 0 0 |

## TABLE XIV.

**PARALLAX IN ALTITUDE OF A PLANET.**

| Alt. | Planet's Horizontal Parallax. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1″ | 2″ | 3″ | 4″ | 5″ | 6″ | 7″ | 8″ | 9″ | 10″ | 20″ | 30″ |
| 5° | 1″·0 | 2″·0 | 3″·0 | 4″·0 | 5″·0 | 6″·0 | 7″·0 | 8″·0 | 9″·0 | 10″·0 | 19″·9 | 29″·9 |
| 10 | 1·0 | 2·0 | 2·9 | 3·9 | 4·9 | 5·9 | 6·9 | 7·9 | 8·9 | 9·8 | 19·7 | 29·5 |
| 15 | 1·0 | 2·0 | 2·9 | 3·8 | 4·8 | 5·8 | 6·8 | 7·7 | 8·7 | 9·7 | 19·3 | 29·0 |
| 20 | 0·9 | 1·9 | 2·8 | 3·7 | 4·6 | 5·6 | 6·5 | 7·5 | 8·5 | 9·4 | 18·8 | 28·2 |
| 25 | 0·9 | 1·9 | 2·7 | 3·6 | 4·5 | 5·4 | 6·3 | 7·3 | 8·2 | 9·1 | 18·1 | 27·2 |
| 30 | 0·9 | 1·8 | 2·6 | 3·5 | 4·3 | 5·2 | 6·1 | 7·0 | 7·8 | 8·7 | 17·3 | 26·0 |
| 35 | 0·8 | 1·6 | 2·5 | 3·3 | 4·1 | 4·9 | 5·7 | 6·6 | 7·4 | 8·2 | 16·4 | 24·6 |
| 40 | 0·8 | 1·5 | 2·3 | 3·1 | 3·8 | 4·6 | 5·4 | 6·1 | 6·9 | 7·7 | 15·3 | 23·0 |
| 45 | 0·7 | 1·4 | 2·1 | 2·8 | 3·5 | 4·2 | 4·9 | 5·7 | 6·4 | 7·1 | 14·1 | 21·2 |
| 50 | 0·7 | 1·3 | 2·0 | 2·5 | 3·2 | 3·9 | 4·5 | 5·1 | 5·8 | 6·4 | 12·9 | 19·3 |
| 55 | 0·6 | 1·1 | 1·7 | 2·3 | 2·8 | 3·4 | 4·0 | 4·6 | 5·2 | 5·7 | 11·5 | 17·2 |
| 60 | 0·5 | 1·0 | 1·5 | 2·0 | 2·5 | 3·0 | 3·5 | 4·0 | 4·5 | 5·0 | 10·5 | 15·0 |
| 62 | 0·5 | 0·9 | 1·4 | 1·9 | 2·3 | 2·8 | 3·3 | 3·8 | 4·2 | 4·7 | 9·4 | 14·1 |
| 64 | 0·4 | 0·9 | 1·3 | 1·8 | 2·2 | 2·6 | 3·1 | 3·5 | 3·9 | 4·4 | 8·8 | 13·1 |
| 66 | 0·4 | 0·8 | 1·2 | 1·6 | 2·0 | 2·4 | 2·8 | 3·3 | 3·7 | 4·1 | 8·1 | 12·2 |
| 68 | 0·4 | 0·7 | 1·1 | 1·5 | 1·8 | 2·2 | 2·6 | 3·0 | 3·4 | 3·7 | 7·5 | 11·2 |
| 70 | 0·3 | 0·7 | 1·0 | 1·4 | 1·7 | 2·1 | 2·4 | 2·7 | 3·1 | 3·4 | 6·8 | 10·3 |
| 72 | 0·3 | 0·6 | 0·9 | 1·2 | 1·5 | 1·9 | 2·2 | 2·5 | 2·8 | 3·1 | 6·2 | 9·3 |
| 74 | 0·3 | 0·6 | 0·8 | 1·1 | 1·3 | 1·7 | 1·9 | 2·2 | 2·5 | 2·7 | 5·5 | 8·3 |
| 76 | 0·2 | 0·5 | 0·7 | 0·9 | 1·2 | 1·5 | 1·7 | 1·9 | 2·2 | 2·4 | 4·8 | 7·3 |
| 78 | 0·2 | 0·4 | 0·6 | 0·8 | 1·0 | 1·2 | 1·4 | 1·7 | 1·9 | 2·1 | 4·2 | 6·2 |
| 80 | 0·2 | 0·3 | 0·5 | 0·7 | 0·8 | 1·0 | 1·2 | 1·4 | 1·6 | 1·7 | 3·5 | 5·2 |
| 82 | 0·1 | 0·3 | 0·4 | 0·6 | 0·7 | 0·8 | 1·0 | 1·1 | 1·2 | 1·4 | 2·8 | 4·2 |
| 84 | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 | 0·6 | 0·7 | 0·8 | 0·9 | 1·0 | 2·1 | 3·1 |
| 86 | 0·1 | 0·1 | 0·2 | 0·3 | 0·3 | 0·4 | 0·5 | 0·6 | 0·6 | 0·7 | 1·4 | 2·1 |
| 88 | 0·0 | 0·1 | 0·1 | 0·1 | 0·1 | 0·2 | 0·2 | 0·3 | 0·3 | 0·3 | 0·7 | 1·0 |
| 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE XV.

LIMITS, AT SEA, OF THE

REDUCTION TO THE MERIDIAN.

| Lat. | Declination of the *same* Name as the Lat. | | | | | |
|---|---|---|---|---|---|---|
| | 0° | 5° | 10° | 15° | 20° | 24° |
| | h m | h m | h m | h m | h m | h m |
| 0° | 0 0 | 0 3 | 0 5 | 0 8 | 0 11 | 0 14 |
| 5 | 0 2 | 0 0 | 0 3 | 0 5 | 0 8 | 0 11 |
| 10 | 0 5 | 0 3 | 0 0 | 0 3 | 0 6 | 0 8 |
| 15 | 0 8 | 0 6 | 0 3 | 0 0 | 0 3 | 0 6 |
| 20 | 0 11 | 0 9 | 0 6 | 0 3 | 0 0 | 0 3 |
| 25 | 0 15 | 0 12 | 0 9 | 0 6 | 0 3 | 0 0 |
| 30 | 0 18 | 0 15 | 0 12 | 0 10 | 0 7 | 0 4 |
| 35 | 0 22 | 0 19 | 0 16 | 0 13 | 0 10 | 0 8 |
| 40 | 0 26 | 0 23 | 0 20 | 0 17 | 0 14 | 0 12 |
| 44 | 0 30 | 0 27 | 0 24 | 0 21 | 0 18 | 0 17 |
| 48 | 0 34 | 0 31 | 0 28 | 0 27 | 0 23 | 0 22 |
| 52 | 0 40 | 0 37 | 0 34 | 0 32 | 0 30 | 0 28 |
| 56 | 0 50 | 0 43 | 0 40 | 0 38 | 0 36 | 0 33 |
| 60 | 0 54 | 0 50 | 0 48 | 0 46 | 0 43 | 0 40 |
| 64 | 1 0 | 0 57 | 0 55 | 0 54 | 0 52 | 0 50 |
| 68 | 1 10 | 1 8 | 1 6 | 1 6 | 1 5 | 1 2 |
| | Declination of *contrary* Name to the Lat. | | | | | |
| 0 | 0 0 | 0 3 | 0 5 | 0 8 | 0 11 | 0 14 |
| 5 | 0 2 | 0 5 | 0 7 | 0 11 | 0 14 | 0 16 |
| 10 | 0 5 | 0 8 | 0 11 | 0 14 | 0 17 | 0 19 |
| 15 | 0 8 | 0 11 | 0 14 | 0 17 | 0 19 | 0 22 |
| 20 | 0 11 | 0 14 | 0 17 | 0 20 | 0 22 | 0 25 |
| 25 | 0 15 | 0 17 | 0 20 | 0 23 | 0 25 | 0 28 |
| 30 | 0 18 | 0 21 | 0 23 | 0 26 | 0 29 | 0 31 |
| 35 | 0 22 | 0 25 | 0 27 | 0 30 | 0 33 | 0 35 |
| 40 | 0 26 | 0 29 | 0 31 | 0 34 | 0 37 | 0 39 |
| 44 | 0 30 | 0 33 | 0 35 | 0 39 | 0 42 | 0 44 |
| 48 | 0 34 | 0 38 | 0 41 | 0 44 | 0 47 | 0 49 |
| 52 | 0 40 | 0 44 | 0 48 | 0 51 | 0 54 | 0 56 |
| 56 | 0 46 | 0 50 | 0 53 | 0 56 | 0 59 | 1 1 |
| 60 | 0 54 | 0 57 | 1 0 | 1 2 | 1 5 | 1 7 |
| 64 | 1 0 | 1 5 | 1 10 | | | |
| 68 | 1 10 | 1 15 | 1 20 | while visible. | | |

## TABLE XVI.

VALUE OF

THE REDUCTION.

AT WHICH THE

2d REDn AMOUNTS TO 1′.

| Mer. Alt. | Reduc. | Mer. Alt. | Reduc. |
|---|---|---|---|
| 5° | 4°40′ | 45° | 1°23′ |
| 6 | 4 16 | 46 | 1 21 |
| 7 | 3 57 | 47 | 1 20 |
| 8 | 3 41 | 48 | 1 19 |
| 9 | 3 28 | 49 | 1 17 |
| 10 | 3 18 | 50 | 1 16 |
| 11 | 3 8 | 51 | 1 15 |
| 12 | 3 0 | 52 | 1 13 |
| 13 | 2 53 | 53 | 1 12 |
| 14 | 2 46 | 54 | 1 11 |
| 15 | 2 40 | 55 | 1 9 |
| 16 | 2 35 | 56 | 1 8 |
| 17 | 2 30 | 57 | 1 7 |
| 18 | 2 25 | 58 | 1 6 |
| 19 | 2 21 | 59 | 1 4 |
| 20 | 2 17 | 60 | 1 3 |
| 21 | 2 14 | 61 | 1 2 |
| 22 | 2 10 | 62 | 1 0 |
| 23 | 2 7 | 63 | 0 59 |
| 24 | 2 4 | 64 | 0 58 |
| 25 | 2 2 | 65 | 0 57 |
| 26 | 1 59 | 66 | 0 55 |
| 27 | 1 56 | 67 | 0 54 |
| 28 | 1 54 | 68 | 0 53 |
| 29 | 1 51 | 69 | 0 52 |
| 30 | 1 49 | 70 | 0 50 |
| 31 | 1 47 | 71 | 0 49 |
| 32 | 1 45 | 72 | 0 47 |
| 33 | 1 43 | 73 | 0 46 |
| 34 | 1 41 | 74 | 0 44 |
| 35 | 1 39 | 75 | 0 43 |
| 36 | 1 37 | 76 | 0 41 |
| 37 | 1 36 | 77 | 0 40 |
| 38 | 1 34 | 78 | 0 38 |
| 39 | 1 32 | 79 | 0 37 |
| 40 | 1 31 | 80 | 0 35 |
| 41 | 1 29 | 81 | 0 33 |
| 42 | 1 27 | 82 | 0 31 |
| 43 | 1 26 | 83 | 0 29 |
| 44 | 1 24 | 84 | 0 27 |

## LOGARITHMS FOR COMPUTING THE REDUCTION TO THE MERIDIAN, AT SEA.

PART I. Latitude and Declination of the *same* name.

| Lat. | DECLINATION. | | | | | | | | | | | | Lat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0° | 1° | 2° | 3° | 4° | 5° | 6° | 7° | 8° | 9° | 10° | 11° | |
| 0° | | | | | | 1·359 | 1·279 | 1·212 | 1·153 | 1·101 | 1 055 | 1 012 | 0° |
| 1 | | | | | | | 1·358 | 1·278 | 1·211 | 1·152 | 1·100 | 1 053 | 1 |
| 2 | | | | | | | | 1·357 | 1·277 | 1·209 | 1·151 | 1 098 | 2 |
| 3 | | | | | | | | | 1·356 | 1·276 | 1·208 | 1 149 | 3 |
| 4 | | | | | | | | | | 1·354 | 1·274 | 1 206 | 4 |
| 5 | 1·359 | | | | | | | | | | 1·352 | 1 272 | 5 |
| 6 | 1 279 | 1·358 | | | | | | | | | | 1·350 | 6 |
| 7 | 1 212 | 1·278 | 1·357 | | | | | | | | | | 7 |
| 8 | 1 153 | 1·211 | 1·277 | 1·356 | | | | | | | | | 8 |
| 9 | 1 101 | 1·152 | 1·209 | 1·276 | 1·354 | | | | | | | | 9 |
| 10 | 1 055 | 1·100 | 1·151 | 1·208 | 1·273 | 1·352 | | | | | | | 10 |
| 11 | 1 012 | 1·053 | 1·098 | 1·149 | 1·206 | 1·272 | 1·350 | | | | | | 11 |
| 12 | 0 974 | 1 011 | 1·051 | 1·097 | 1·147 | 1·204 | 1·270 | 1·348 | | | | | 12 |
| 13 | 0 938 | 0 972 | 1·009 | 1 051 | 1·094 | 1·145 | 1·201 | 1·267 | 1·345 | | | | 13 |
| 14 | 0 904 | 0 936 | 0·970 | 1·007 | 1 047 | 1·092 | 1·142 | 1·199 | 1·264 | 1·342 | | | 14 |
| 15 | 0 873 | 0 902 | 0·934 | 0 967 | 1 004 | 1·045 | 1·089 | 1·139 | 1·196 | 1·261 | 1·339 | | 15 |
| 16 | 0 844 | 0 871 | 0·900 | 0 931 | 0 965 | 1·002 | 1 042 | 1·086 | 1·136 | 1·193 | 1·258 | 1·336 | 16 |
| 17 | 0 816 | 0 841 | 0·868 | 0 897 | 0 928 | 0 962 | 0 999 | 1·039 | 1·083 | 1·133 | 1·189 | 1·254 | 17 |
| 18 | 0 789 | 0 813 | 0·839 | 0 866 | 0 895 | 0 925 | 0 959 | 0·995 | 1·035 | 1·080 | 1·129 | 1·185 | 18 |
| 19 | 0 764 | 0 787 | 0 811 | 0 836 | 0 863 | 0 891 | 0 922 | 0 956 | 0·992 | 1 032 | 1·076 | 1·125 | 19 |
| 20 | 0 740 | 0 761 | 0 784 | 0 807 | 0 833 | 0 859 | 0 888 | 0 919 | 0·952 | 0 988 | 1 028 | 1 072 | 20 |
| 21 | 0 717 | 0 737 | 0 758 | 0 781 | 0 804 | 0 829 | 0 856 | 0·884 | 0·915 | 0 948 | 0 984 | 0 023 | 21 |
| 22 | 0 695 | 0 714 | 0 734 | 0 755 | 0 777 | 0 801 | 0 825 | 0·852 | 0·880 | 0 911 | 0 944 | 0 980 | 22 |
| 23 | 0 673 | 0 691 | 0 710 | 0 730 | 0 752 | 0 773 | 0 807 | 0 821 | 0 848 | 0 876 | 0·906 | 0 939 | 23 |
| 24 | 0 652 | 0 670 | 0 688 | 0 707 | 0 727 | 0 747 | 0·769 | 0 793 | 0·817 | 0 844 | 0·871 | 0 902 | 24 |
| 25 | 0 632 | 0 649 | 0 666 | 0 684 | 0 703 | 0 723 | 0 743 | 0·765 | 0·788 | 0 813 | 0 839 | 0 867 | 25 |
| 26 | 0 613 | 0 629 | 0 645 | 0 662 | 0 680 | 0 699 | 0·718 | 0 739 | 0 760 | 0·783 | 0 808 | 0 834 | 26 |
| 27 | 0 594 | 0 609 | 0 625 | 0 641 | 0 658 | 0 676 | 0 694 | 0·714 | 0·734 | 0 756 | 0·778 | 0 803 | 27 |
| 28 | 0 575 | 0 590 | 0 605 | 0 620 | 0 637 | 0 653 | 0 671 | 0 689 | 0·709 | 0 729 | 0·750 | 0 773 | 28 |
| 29 | 0 557 | 0 571 | 0 586 | 0 600 | 0 616 | 0 632 | 0 649 | 0·666 | 0 684 | 0·703 | 0 724 | 0 745 | 29 |
| 30 | 0·540 | 0·553 | 0·567 | 0·581 | 0 596 | 0 611 | 0 627 | 0 643 | 0 661 | 0 679 | 0 698 | 0 718 | 30 |
| 31 | 0 522 | 0 535 | 0·548 | 0 562 | 0 576 | 0 591 | 0 606 | 0 622 | 0 638 | 0 655 | 0·673 | 0 692 | 31 |
| 32 | 0 505 | 0 518 | 0 530 | 0 543 | 0·557 | 0 571 | 0·585 | 0 600 | 0 616 | 0 632 | 0 649 | 0 667 | 32 |
| 33 | 0 489 | 0 500 | 0 513 | 0 525 | 0 538 | 0 551 | 0·565 | 0·580 | 0·594 | 0 610 | 0 626 | 0 643 | 33 |
| 34 | 0 472 | 0·483 | 0·495 | 0 507 | 0 519 | 0 532 | 0 546 | 0·559 | 0·574 | 0 588 | 0 604 | 0 620 | 34 |
| 35 | 0 456 | 0 467 | 0·478 | 0 489 | 0 501 | 0 514 | 0 526 | 0 540 | 0 553 | 0 567 | 0·582 | 0 597 | 35 |
| 36 | 0 440 | 0 450 | 0·461 | 0 472 | 0·484 | 0 495 | 0·508 | 0·520 | 0·533 | 0 548 | 0·560 | 0·575 | 36 |
| 37 | 0 424 | 0·434 | 0 445 | 0·455 | 0 466 | 0 478 | 0·489 | 0·501 | 0·514 | 0·526 | 0·540 | 0 553 | 37 |
| 38 | 0 408 | 0 418 | 0 428 | 0 438 | 0 449 | 0·460 | 0·471 | 0·482 | 0·494 | 0 507 | 0·519 | 0 532 | 38 |
| 39 | 0 393 | 0·402 | 0·412 | 0 422 | 0 432 | 0 442 | 0 453 | 0 464 | 0·475 | 0·487 | 0·499 | 0 512 | 39 |
| 40 | 0 377 | 0·396 | 0 396 | 0 405 | 0·415 | 0 425 | 0·435 | 0·447 | 0·457 | 0·468 | 0 480 | 0 492 | 40 |
| 41 | 0 362 | 0 371 | 0 380 | 0 389 | 0 398 | 0 408 | 0·418 | 0·428 | 0·438 | 0·449 | 0·460 | 0 472 | 41 |
| 42 | 0 347 | 0 355 | 0·364 | 0 373 | 0 382 | 0 391 | 0·400 | 0·410 | 0·420 | 0 431 | 0·441 | 0·452 | 42 |
| 43 | 0 331 | 0 340 | 0 348 | 0 356 | 0 365 | 0 374 | 0·383 | 0·393 | 0·402 | 0 412 | 0·422 | 0 433 | 43 |
| 44 | 0 316 | 0 324 | 0·332 | 0 340 | 0 349 | 0·357 | 0 366 | 0 375 | 0·384 | 0·394 | 0·404 | 0 414 | 44 |
| 45 | 0 301 | 0·309 | 0·316 | 0 324 | 0·333 | 0 341 | 0 349 | 0·358 | 0·367 | 0·376 | 0 385 | 0 395 | 45 |
| 46 | 0·286 | 0 293 | 0·301 | 0·308 | 0·316 | 0 324 | 0·332 | 0·341 | 0·349 | 0 358 | 0·367 | 0 376 | 46 |
| 47 | 0 271 | 0 278 | 0 285 | 0 292 | 0 300 | 0 308 | 0·315 | 0·323 | 0·331 | 0·340 | 0·349 | 0 358 | 47 |
| 48 | 0 255 | 0 262 | 0·269 | 0·276 | 0 284 | 0 291 | 0·299 | 0 306 | 0·314 | 0·322 | 0·331 | 0·339 | 48 |
| 49 | 0 240 | 0 247 | 0 254 | 0·260 | 0 267 | 0·275 | 0·282 | 0·289 | 0·297 | 0 305 | 0·312 | 0 321 | 49 |
| 50 | 0 225 | 0 231 | 0 238 | 0 244 | 0·251 | 0 258 | 0·265 | 0·272 | 0·279 | 0·287 | 0 294 | 0 302 | 50 |
| 51 | 0 209 | 0·216 | 0·222 | 0 228 | 0·235 | 0 241 | 0·248 | 0·255 | 0·262 | 0·269 | 0·276 | 0 284 | 51 |
| 52 | 0·194 | 0·200 | 0·206 | 0·212 | 0·218 | 0 225 | 0·231 | 0·238 | 0·244 | 0·251 | 0·258 | 0·265 | 52 |
| 53 | 0·178 | 0·184 | 0·190 | 0 196 | 0 202 | 0·208 | 0·214 | 0·220 | 0·227 | 0·233 | 0·240 | 0·247 | 53 |
| 54 | 0 162 | 0 168 | 0·173 | 0 179 | 0 185 | 0 191 | 0·197 | 0·203 | 0·209 | 0·215 | 0·222 | 0·228 | 54 |
| 55 | 0 146 | 0 152 | 0·157 | 0·162 | 0·168 | 0·174 | 0·179 | 0·185 | 0·191 | 0·197 | 0·204 | 0·210 | 55 |
| 56 | 0·130 | 0·135 | 0·140 | 0·146 | 0·151 | 0·156 | 0·162 | 0·168 | 0·173 | 0·179 | 0·185 | 0·191 | 56 |
| 57 | 0·114 | 0·118 | 0·124 | 0 129 | 0·134 | 0·139 | 0·144 | 0·150 | 0·155 | 0·160 | 0·166 | 0·172 | 57 |
| 58 | 0 097 | 0·100 | 0·106 | 0·111 | 0 116 | 0 121 | 0·126 | 0·131 | 0·137 | 0·142 | 0·148 | 0·153 | 58 |
| 59 | 0 080 | 0·084 | 0·089 | 0 094 | 0 098 | 0·103 | 0·108 | 0·113 | 0·118 | 0·123 | 0·128 | 0·134 | 59 |
| 60 | 0·062 | 0·067 | 0·071 | 0 076 | 0 080 | 0 085 | 0 090 | 0·094 | 0·099 | 0·104 | 0 109 | 0 114 | 60 |
| 61 | 0·045 | 0·049 | 0·053 | 0 058 | 0 062 | 0 066 | 0·071 | 0·075 | 0·080 | 0·085 | 0·089 | 0·094 | 61 |
| 62 | 0·027 | 0·031 | 0·035 | 0 039 | 0·043 | 0·047 | 0·052 | 0·056 | 0·060 | 0·065 | 0·069 | 0·074 | 62 |

## LOGARITHMS FOR COMPUTING THE REDUCTION TO THE MERIDIAN, AT SEA.

PART I. Latitude and Declination of the *same* name.

| Lat. | DECLINATION. | | | | | | | | | | | | Lat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12° | 13° | 14° | 15° | 16° | 17° | 18° | 19° | 20° | 21° | 22° | 23° | |
| 0° | 0·974 | 0·938 | 0·904 | 0·873 | 0·844 | 0·816 | 0·789 | 0·764 | 0·740 | 0·717 | 0·695 | 0·673 | 0° |
| 1 | 1·011 | 0·972 | 0 936 | 0·902 | 0 871 | 0·841 | 0 813 | 0·787 | 0·761 | 0·737 | 0·714 | 0·691 | 1 |
| 2 | 1·051 | 1·009 | 0 970 | 0·934 | 0·900 | 0 868 | 0 839 | 0 811 | 0·784 | 0·758 | 0·734 | 0·710 | 2 |
| 3 | 1·097 | 1·049 | 1 007 | 0 967 | 0·931 | 0 897 | 0 866 | 0 836 | 0·807 | 0·781 | 0·755 | 0·730 | 3 |
| 4 | 1·147 | 1·094 | 1·047 | 1·004 | 0·965 | 0 928 | 0·895 | 0 863 | 0·832 | 0·804 | 0·777 | 0·751 | 4 |
| 5 | 1·204 | 1·145 | 1·092 | 1·045 | 1·002 | 0 962 | 0·925 | 0 891 | 0 859 | 0·829 | 0·801 | 0·773 | 5 |
| 6 | 1·270 | 1·201 | 1·142 | 1·089 | 1·042 | 0·999 | 0·959 | 0 922 | 0 888 | 0·856 | 0·825 | 0·797 | 6 |
| 7 | 1·348 | 1·267 | 1·199 | 1·139 | 1·086 | 1·039 | 0·995 | 0 956 | 0·919 | 0 884 | 0·852 | 0·821 | 7 |
| 8 | | 1.345 | 1·264 | 1·196 | 1·136 | 1·083 | 1·035 | 0 992 | 0·952 | 0·915 | 0·880 | 0·848 | 8 |
| 9 | | | 1·342 | 1·261 | 1·191 | 1·133 | 1·080 | 1·032 | 0 988 | 0·948 | 0·911 | 0·876 | 9 |
| 10 | | | | 1·339 | 1·258 | 1·189 | 1·129 | 1·076 | 1·028 | 0·984 | 0·944 | 0·906 | 10 |
| 11 | | | | | 1·336 | 1·254 | 1·185 | 1·125 | 1·072 | 1·023 | 0·980 | 0·939 | 11 |
| 12 | | | | | | 1·332 | 1·250 | 1·181 | 1·121 | 1·067 | 1·019 | 0·975 | 12 |
| 13 | | | | | | | 1·328 | 1·246 | 1·177 | 1·116 | 1·063 | 1·014 | 13 |
| 14 | | | | | | | | 1·323 | 1·242 | 1·172 | 1·112 | 1·058 | 14 |
| 15 | | | | | | | | | 1·319 | 1·237 | 1·167 | 1·106 | 15 |
| 16 | | | | | | | | | | 1·314 | 1·232 | 1·162 | 16 |
| 17 | 1·332 | | | | | | | | | | 1·308 | 1·226 | 17 |
| 18 | 1·250 | 1·328 | | | | | | | | | | 1·303 | 18 |
| 19 | 1·181 | 1.246 | 1·323 | | | | | | | | | | 19 |
| 20 | 1·121 | 1·177 | 1·242 | 1·319 | | | | | | | | | 20 |
| 21 | 1·067 | 1·116 | 1·172 | 1·237 | 1·314 | | | | | | | | 21 |
| 22 | 1·019 | 1·063 | 1·112 | 1·167 | 1·232 | 1·308 | | | | | | | 22 |
| 23 | 0·975 | 1·014 | 1·058 | 1·106 | 1·162 | 1·226 | 1·303 | | | | | | 23 |
| 24 | 0·934 | 0·970 | 1·009 | 1·052 | 1·101 | 1·156 | 1·221 | 1·297 | | | | | 24 |
| 25 | 0·897 | 0·929 | 0·965 | 1·004 | 1·047 | 1·095 | 1·151 | 1·215 | 1·291 | | | | 25 |
| 26 | 0·861 | 0·890 | 0·924 | 0·959 | 0 998 | 1·041 | 1·090 | 1·144 | 1·208 | 1·285 | | | 26 |
| 27 | 0·828 | 0·856 | 0 886 | 0·918 | 0 953 | 0·992 | 1·035 | 1·083 | 1·138 | 1·202 | 1·278 | | 27 |
| 28 | 0·797 | 0.823 | 0·850 | 0·880 | 0 912 | 0·947 | 0·986 | 1·028 | 1·076 | 1·131 | 1·195 | 1·271 | 28 |
| 29 | 0·767 | 0·791 | 0 817 | 0 844 | 0 874 | 0·906 | 0·940 | 0·979 | 1·021 | 1·069 | 1·124 | 1·188 | 29 |
| 30 | 0·739 | 0·761 | 0·785 | 0 811 | 0 838 | 0 867 | 0·899 | 0·934 | 0·972 | 1 014 | 1·062 | 1·117 | 30 |
| 31 | 0·712 | 0·733 | 0·755 | 0·779 | 0 804 | 0 831 | 0·860 | 0·892 | 0 926 | 0·965 | 1·007 | 1·055 | 31 |
| 32 | 0·686 | 0·706 | 0·726 | 0·748 | 0·772 | 0·797 | 0·824 | 0·853 | 0 885 | 0·919 | 0·957 | 0·999 | 32 |
| 33 | 0·661 | 0·679 | 0·699 | 0·720 | 0·742 | 0·765 | 0·790 | 0·817 | 0 846 | 0·877 | 0·911 | 0·949 | 33 |
| 34 | 0·636 | 0·654 | 0·672 | 0·692 | 0·712 | 0·734 | 0·757 | 0·782 | 0 809 | 0·838 | 0·869 | 0 903 | 34 |
| 35 | 0·612 | 0 630 | 0·647 | 0·665 | 0·685 | 0·705 | 0·727 | 0·750 | 0·774 | 0 801 | 0·829 | 0·861 | 35 |
| 36 | 0·590 | 0·606 | 0·622 | 0·640 | 0·658 | 0·677 | 0·697 | 0·719 | 0·742 | 0·766 | 0·792 | 0·821 | 36 |
| 37 | 0·568 | 0·583 | 0 598 | 0·615 | 0·632 | 0 650 | 0·669 | 0·689 | 0·710 | 0·733 | 0·758 | 0·784 | 37 |
| 38 | 0·546 | 0·560 | 0·575 | 0 591 | 0·607 | 0·624 | 0·642 | 0·661 | 0 681 | 0·702 | 0·724 | 0·749 | 38 |
| 39 | 0·525 | 0·538 | 0·552 | 0·567 | 0·582 | 0·599 | 0·615 | 0·633 | 0 652 | 0 672 | 0·693 | 0·715 | 39 |
| 40 | 0·504 | 0·517 | 0 530 | 0·544 | 0·559 | 0·574 | 0·590 | 0·607 | 0 624 | 0·643 | 0·662 | 0·683 | 40 |
| 41 | 0·484 | 0·496 | 0·509 | 0·522 | 0·536 | 0·550 | 0·565 | 0·581 | 0·597 | 0·615 | 0·633 | 0·653 | 41 |
| 42 | 0·464 | 0·475 | 0·487 | 0·500 | 0·513 | 0·527 | 0·541 | 0·556 | 0·572 | 0·588 | 0·605 | 0·623 | 42 |
| 43 | 0·444 | 0·455 | 0·466 | 0·478 | 0·491 | 0·504 | 0·517 | 0·532 | 0·546 | 0·562 | 0·578 | 0·595 | 43 |
| 44 | 0·424 | 0·435 | 0·446 | 0·457 | 0·469 | 0·482 | 0·494 | 0·508 | 0·522 | 0·536 | 0·552 | 0·568 | 44 |
| 45 | 0·405 | 0·415 | 0·426 | 0·436 | 0·448 | 0·460 | 0·472 | 0·484 | 0·498 | 0·511 | 0·526 | 0·541 | 45 |
| 46 | 0·386 | 0·395 | 0·405 | 0·416 | 0·427 | 0·438 | 0·449 | 0·461 | 0·474 | 0·487 | 0·501 | 0·515 | 46 |
| 47 | 0·367 | 0·376 | 0·386 | 0·396 | 0·406 | 0·416 | 0·427 | 0·439 | 0·451 | 0·463 | 0·476 | 0·490 | 47 |
| 48 | 0·348 | 0·357 | 0·366 | 0·375 | 0·385 | 0·395 | 0·406 | 0·417 | 0·428 | 0·440 | 0·452 | 0·465 | 48 |
| 49 | 0·329 | 0·337 | 0·346 | 0·355 | 0·365 | 0·374 | 0·384 | 0·395 | 0·405 | 0·417 | 0·428 | 0·440 | 49 |
| 50 | 0·310 | 0·318 | 0·327 | 0·335 | 0·344 | 0·354 | 0·363 | 0·373 | 0·383 | 0·394 | 0·405 | 0·416 | 50 |
| 51 | 0·291 | 0·299 | 0·307 | 0·316 | 0·324 | 0·333 | 0·342 | 0·351 | 0·361 | 0·371 | 0·381 | 0·392 | 51 |
| 52 | 0·273 | 0·280 | 0·288 | 0·296 | 0·304 | 0·312 | 0·321 | 0·330 | 0·339 | 0·349 | 0·359 | 0·369 | 52 |
| 53 | 0·254 | 0·261 | 0·269 | 0·276 | 0·284 | 0·292 | 0·300 | 0·309 | 0·317 | 0·326 | 0·336 | 0·346 | 53 |
| 54 | 0·235 | 0·242 | 0·249 | 0·257 | 0·264 | 0·271 | 0·279 | 0·287 | 0·296 | 0·304 | 0·313 | 0·322 | 54 |
| 55 | 0·216 | 0·223 | 0·230 | 0·236 | 0·244 | 0·251 | 0·258 | 0·266 | 0·274 | 0·282 | 0·291 | 0·299 | 55 |
| 56 | 0·197 | 0·204 | 0·210 | 0·217 | 0·223 | 0·230 | 0·237 | 0·245 | 0·252 | 0·260 | 0·268 | 0·277 | 56 |
| 57 | 0·178 | 0·184 | 0·190 | 0·197 | 0·203 | 0·210 | 0·216 | 0·223 | 0·231 | 0·238 | 0·246 | 0·254 | 57 |
| 58 | 0·159 | 0·164 | 0·170 | 0·176 | 0·183 | 0·189 | 0·195 | 0·202 | 0·209 | 0·216 | 0·223 | 0·231 | 58 |
| 59 | 0·139 | 0·145 | 0·150 | 0·156 | 0·162 | 0·168 | 0·174 | 0·180 | 0·187 | 0·194 | 0·201 | 0·208 | 59 |
| 60 | 0·119 | 0·125 | 0·130 | 0·135 | 0·141 | 0·147 | 0·153 | 0·159 | 0·165 | 0·171 | 0·178 | 0·185 | 60 |
| 61 | 0·099 | 0·104 | 0·109 | 0·115 | 0·120 | 0·125 | 0·131 | 0·137 | 0·143 | 0·149 | 0·155 | 0·161 | 61 |
| 62 | 0·079 | 0·084 | 0·088 | 0·093 | 0·099 | 0·104 | 0·110 | 0·115 | 0·120 | 0·126 | 0·132 | 0·138 | 62 |

## LOGARITHMS FOR COMPUTING THE REDUCTION TO THE MERIDIAN, AT SEA.

**PART II. Latitude and Declination of *contrary* names.**

| Lat. | DECLINATION. | | | | | | | | | | | | Lat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0° | 1° | 2° | 3° | 4° | 5° | 6° | 7° | 8° | 9° | 10° | 11° | |
| 0° | | | | | | 1·359 | 1·279 | 1·212 | 1·153 | 1·101 | 1·055 | 1·012 | 0° |
| 1 | | | | | 1·360 | 1·280 | 1·213 | 1·154 | 1·102 | 1·056 | 1·014 | 0·975 | 1 |
| 2 | | | | 1·360 | 1·281 | 1·213 | 1·155 | 1·103 | 1·057 | 1·015 | 0·976 | 0·941 | 2 |
| 3 | | | 1·360 | 1·281 | 1·213 | 1·155 | 1·104 | 1·058 | 1·016 | 0·977 | 0·942 | 0·909 | 3 |
| 4 | | 1·360 | 1·280 | 1·213 | 1·155 | 1·104 | 1·058 | 1·016 | 0·978 | 0·943 | 0·910 | 0·879 | 4 |
| 5 | 1·359 | 1·280 | 1·213 | 1·155 | 1·104 | 1·058 | 1·016 | 0·978 | 0·943 | 0·910 | 0·880 | 0·851 | 5 |
| 6 | 1·279 | 1·213 | 1·155 | 1·104 | 1·058 | 1·016 | 0·979 | 0·943 | 0·911 | 0·880 | 0·852 | 0·825 | 6 |
| 7 | 1·212 | 1·154 | 1·103 | 1·058 | 1·016 | 0·978 | 0·943 | 0·911 | 0·881 | 0 851 | 0·825 | 0·800 | 7 |
| 8 | 1·153 | 1·102 | 1·057 | 1·016 | 0·978 | 0·943 | 0·911 | 0·881 | 0·852 | 0·825 | 0·800 | 0·776 | 8 |
| 9 | 1·101 | 1·056 | 1·015 | 0·977 | 0·943 | 0·910 | 0·880 | 0·852 | 0·825 | 0·800 | 0·776 | 0·754 | 9 |
| 10 | 1 055 | 1·014 | 0·976 | 0·942 | 0·910 | 0·880 | 0·852 | 0·825 | 0·800 | 0·776 | 0·754 | 0·732 | 10 |
| 11 | 1·012 | 0·975 | 0·941 | 0·909 | 0·879 | 0·851 | 0 825 | 0·800 | 0·776 | 0·754 | 0·732 | 0·711 | 11 |
| 12 | 0·974 | 0·939 | 0·907 | 0·878 | 0·850 | 0·824 | 0·799 | 0·775 | 0·753 | 0·732 | 0·711 | 0·692 | 12 |
| 13 | 0·938 | 0·906 | 0·876 | 0·849 | 0·823 | 0·798 | 0·775 | 0·752 | 0·731 | 0·711 | 0·691 | 0·672 | 13 |
| 14 | 0·904 | 0·875 | 0·847 | 0·821 | 0·797 | 0·774 | 0·751 | 0·730 | 0·710 | 0·691 | 0·672 | 0·654 | 14 |
| 15 | 0·873 | 0·846 | 0·820 | 0·795 | 0·772 | 0·750 | 0·729 | 0·709 | 0·690 | 0·671 | 0·653 | 0·636 | 15 |
| 16 | 0·844 | 0·818 | 0·794 | 0·771 | 0·749 | 0·728 | 0·708 | 0·689 | 0·670 | 0·653 | 0·635 | 0·619 | 16 |
| 17 | 0·816 | 0·792 | 0·769 | 0·747 | 0·726 | 0·706 | 0 687 | 0·669 | 0·651 | 0·634 | 0·617 | 0·602 | 17 |
| 18 | 0·789 | 0·767 | 0·745 | 0·724 | 0·705 | 0 686 | 0 668 | 0·650 | 0·633 | 0·617 | 0·601 | 0·586 | 18 |
| 19 | 0·764 | 0·743 | 0·722 | 0·703 | 0·684 | 0·666 | 0 648 | 0·632 | 0 615 | 0·600 | 0·584 | 0·570 | 19 |
| 20 | 0·740 | 0·720 | 0·700 | 0·682 | 0·664 | 0 646 | 0 630 | 0·614 | 0 598 | 0·583 | 0·568 | 0·554 | 20 |
| 21 | 0·717 | 0·698 | 0·679 | 0·661 | 0·644 | 0·628 | 0 612 | 0·596 | 0·581 | 0·567 | 0·553 | 0·539 | 21 |
| 22 | 0·695 | 0·676 | 0·659 | 0·642 | 0·625 | 0·609 | 0·594 | 0·579 | 0·565 | 0·551 | 0·537 | 0·524 | 22 |
| 23 | 0·673 | 0·656 | 0·639 | 0·623 | 0·607 | 0·592 | 0·577 | 0·563 | 0·549 | 0·535 | 0·522 | 0·509 | 23 |
| 24 | 0·652 | 0·636 | 0·621 | 0·604 | 0·589 | 0·575 | 0 560 | 0·547 | 0·533 | 0·520 | 0·508 | 0·495 | 24 |
| 25 | 0·632 | 0·616 | 0·601 | 0·586 | 0·572 | 0·558 | 0·544 | 0·531 | 0·518 | 0·505 | 0·493 | 0·481 | 25 |
| 26 | 0·613 | 0·598 | 0·583 | 0·569 | 0·555 | 0·541 | 0·528 | 0·515 | 0·503 | 0·491 | 0·479 | 0·467 | 26 |
| 27 | 0·594 | 0·579 | 0·565 | 0·551 | 0·538 | 0·525 | 0·512 | 0·500 | 0·488 | 0·476 | 0·465 | 0·454 | 27 |
| 28 | 0·575 | 0·561 | 0·548 | 0·535 | 0·522 | 0 509 | 0·497 | 0·485 | 0·473 | 0·462 | 0·451 | 0·440 | 28 |
| 29 | 0·557 | 0·544 | 0·531 | 0·518 | 0·506 | 0·494 | 0 482 | 0·470 | 0·459 | 0·448 | 0·437 | 0·427 | 29 |
| 30 | 0·540 | 0·527 | 0·514 | 0·502 | 0·490 | 0·478 | 0·467 | 0·456 | 0·445 | 0·434 | 0·425 | 0·414 | 30 |
| 31 | 0·522 | 0·510 | 0·498 | 0·486 | 0·474 | 0·463 | 0·452 | 0·442 | 0·431 | 0·421 | 0·411 | 0·401 | 31 |
| 32 | 0·505 | 0·493 | 0·482 | 0·470 | 0·459 | 0·448 | 0·438 | 0·427 | 0·417 | 0·407 | 0·397 | 0·388 | 32 |
| 33 | 0·489 | 0·477 | 0·466 | 0·455 | 0·444 | 0·434 | 0·423 | 0·413 | 0·403 | 0·394 | 0·384 | 0·375 | 33 |
| 34 | 0·472 | 0·461 | 0·450 | 0·440 | 0·429 | 0·419 | 0·409 | 0·399 | 0·390 | 0·380 | 0·371 | 0·362 | 34 |
| 35 | 0·456 | 0·445 | 0·435 | 0·424 | 0·414 | 0·405 | 0·395 | 0·386 | 0·376 | 0·367 | 0·358 | 0·349 | 35 |
| 36 | 0·440 | 0·429 | 0·419 | 0·410 | 0·400 | 0·390 | 0·381 | 0·372 | 0·363 | 0·354 | 0·345 | 0·337 | 36 |
| 37 | 0·424 | 0·414 | 0·404 | 0·395 | 0·385 | 0·376 | 0·367 | 0·358 | 0·350 | 0·341 | 0·333 | 0·324 | 37 |
| 38 | 0·408 | 0·399 | 0·389 | 0·380 | 0·371 | 0·362 | 0·353 | 0·345 | 0·336 | 0·328 | 0·320 | 0·312 | 38 |
| 39 | 0·393 | 0·384 | 0·374 | 0·365 | 0·357 | 0·348 | 0·340 | 0·331 | 0·323 | 0·315 | 0·307 | 0·299 | 39 |
| 40 | 0·377 | 0·368 | 0·360 | 0·351 | 0·342 | 0·334 | 0·326 | 0·318 | 0 310 | 0·302 | 0·294 | 0·287 | 40 |
| 41 | 0·362 | 0·353 | 0·345 | 0·336 | 0·328 | 0·320 | 0·312 | 0·304 | 0·297 | 0·289 | 0·282 | 0·274 | 41 |
| 42 | 0·347 | 0·338 | 0·330 | 0·322 | 0·314 | 0·306 | 0·299 | 0·291 | 0·284 | 0·276 | 0·269 | 0·262 | 42 |
| 43 | 0·331 | 0·323 | 0·315 | 0·308 | 0·300 | 0·292 | 0·285 | 0·278 | 0·270 | 0·263 | 0·256 | 0·249 | 43 |
| 44 | 0·316 | 0·308 | 0·301 | 0·293 | 0·286 | 0·279 | 0·271 | 0·264 | 0·257 | 0·250 | 0·243 | 0·237 | 44 |
| 45 | 0·301 | 0·294 | 0·286 | 0·279 | 0·272 | 0·265 | 0·258 | 0·251 | 0·244 | 0·237 | 0·231 | 0·224 | 45 |
| 46 | 0·286 | 0·279 | 0·271 | 0·264 | 0·257 | 0·251 | 0·244 | 0·237 | 0·231 | 0·224 | 0·218 | 0·211 | 46 |
| 47 | 0·271 | 0·264 | 0·257 | 0·250 | 0·243 | 0·237 | 0·230 | 0·224 | 0·217 | 0·211 | 0·205 | 0·198 | 47 |
| 48 | 0·255 | 0·249 | 0·242 | 0·235 | 0·229 | 0·223 | 0·216 | 0·210 | 0·204 | 0·198 | 0·191 | 0·185 | 48 |
| 49 | 0·240 | 0·234 | 0·227 | 0·221 | 0·215 | 0·208 | 0·202 | 0·196 | 0·190 | 0·184 | 0·178 | 0·172 | 49 |
| 50 | 0·225 | 0·219 | 0·212 | 0·206 | 0·200 | 0·194 | 0·188 | 0·182 | 0·176 | 0·171 | 0·165 | 0·159 | 50 |
| 51 | 0·209 | 0·203 | 0·197 | 0·191 | 0·185 | 0·180 | 0·174 | 0·168 | 0·163 | 0·157 | 0·151 | 0·145 | 51 |
| 52 | 0·194 | 0·188 | 0·182 | 0·176 | 0·171 | 0·165 | 0·160 | 0·154 | 0·149 | 0·143 | 0·138 | 0·132 | 52 |
| 53 | 0·178 | 0·172 | 0·167 | 0·161 | 0·156 | 0·150 | 0·145 | 0·140 | 0·134 | 0·129 | 0·124 | 0·119 | 53 |
| 54 | 0·162 | 0·157 | 0·151 | 0·146 | 0·141 | 0·136 | 0·130 | 0·125 | 0·120 | 0·115 | 0·110 | 0·105 | 54 |
| 55 | 0·146 | 0·141 | 0·136 | 0·131 | 0·125 | 0·120 | 0·115 | 0·110 | 0·105 | 0·101 | 0·096 | 0·091 | 55 |
| 56 | 0·130 | 0·125 | 0·120 | 0·115 | 0·110 | 0·105 | 0·100 | 0·095 | 0·091 | 0·086 | 0·081 | 0·077 | 56 |
| 57 | 0·114 | 0·109 | 0·104 | 0·099 | 0·094 | 0·090 | 0·085 | 0·080 | 0·076 | 0·071 | 0·066 | 0·062 | 57 |
| 58 | 0·097 | 0·092 | 0·087 | 0·083 | 0·078 | 0·074 | 0·069 | 0·065 | 0·060 | 0·056 | 0·051 | 0·047 | 58 |
| 59 | 0·080 | 0·075 | 0·071 | 0·066 | 0·062 | 0·058 | 0·053 | 0·049 | 0·045 | 0·040 | 0·036 | 0·032 | 59 |
| 60 | 0·062 | 0·058 | 0·054 | 0·050 | 0·045 | 0·041 | 0·037 | 0·033 | 0·029 | 0·024 | 0·020 | 0·016 | 60 |
| 61 | 0·045 | 0·041 | 0·036 | 0·032 | 0·028 | 0·024 | 0·020 | 0·016 | 0·012 | 0·008 | 0·004 | 0·000 | 61 |
| 62 | 0·027 | 0·023 | 0·019 | 0·015 | 0·011 | 0·007 | 0·003 | 9·999 | 9·995 | 9·992 | 9·988 | 9·984 | 62 |

## LOGARITHMS FOR COMPUTING THE REDUCTION TO THE MERIDIAN, AT SEA.

PART II. Latitude and Declination of *contrary* names.

| Lat. | Declination. | | | | | | | | | | | Lat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12° | 13° | 14° | 15° | 16° | 17° | 18° | 19° | 20° | 21° | 22° | 23° | |
| 0° | 0·979 | 0·938 | 0·904 | 0·873 | 0·844 | 0·816 | 0·789 | 0·764 | 0·740 | 0·717 | 0·695 | 0 673 | 0° |
| 1 | 0·931 | 0·906 | 0·875 | 0·846 | 0·818 | 0·792 | 0·767 | 0·743 | 0·720 | 0·698 | 0·676 | 0·656 | 1 |
| 2 | 0·907 | 0·876 | 0·847 | 0·820 | 0·794 | 0·769 | 0·745 | 0·722 | 0·700 | 0·679 | 0·659 | 0·639 | 2 |
| 3 | 0·878 | 0·849 | 0·821 | 0·795 | 0·771 | 0·747 | 0·724 | 0·703 | 0·682 | 0·661 | 0·642 | 0·623 | 3 |
| 4 | 0·850 | 0·823 | 0·797 | 0·772 | 0·749 | 0·726 | 0·705 | 0·684 | 0·664 | 0·644 | 0·625 | 0·607 | 4 |
| 5 | 0·824 | 0·798 | 0·774 | 0·750 | 0·728 | 0·706 | 0·686 | 0·666 | 0·646 | 0·628 | 0·609 | 0·592 | 5 |
| 6 | 0·799 | 0·775 | 0·751 | 0·729 | 0·708 | 0·687 | 0·668 | 0·648 | 0·630 | 0·612 | 0·594 | 0·577 | 6 |
| 7 | 0·776 | 0·752 | 0·730 | 0·709 | 0·689 | 0·669 | 0·650 | 0·632 | 0·614 | 0·596 | 0·579 | 0·563 | 7 |
| 8 | 0·753 | 0·731 | 0·710 | 0·690 | 0·670 | 0·651 | 0·633 | 0·615 | 0·598 | 0·581 | 0·565 | 0·549 | 8 |
| 9 | 0·732 | 0·711 | 0·691 | 0·671 | 0·653 | 0·634 | 0·617 | 0·600 | 0·583 | 0·567 | 0·551 | 0·535 | 9 |
| 10 | 0·711 | 0·691 | 0·672 | 0·653 | 0·635 | 0·618 | 0·601 | 0·584 | 0·568 | 0·553 | 0·537 | 0·522 | 10 |
| 11 | 0·692 | 0·672 | 0·654 | 0·636 | 0·619 | 0·602 | 0·586 | 0·570 | 0·554 | 0·539 | 0·524 | 0·509 | 11 |
| 12 | 0·673 | 0·654 | 0·636 | 0·619 | 0·603 | 0·586 | 0·571 | 0·555 | 0·540 | 0·525 | 0·511 | 0·497 | 12 |
| 13 | 0·654 | 0·637 | 0·620 | 0·603 | 0·587 | 0·571 | 0·556 | 0·541 | 0·527 | 0·512 | 0·498 | 0·485 | 13 |
| 14 | 0·636 | 0·620 | 0·603 | 0·587 | 0·572 | 0·557 | 0·542 | 0·527 | 0·513 | 0·499 | 0·486 | 0·473 | 14 |
| 15 | 0·619 | 0·602 | 0·587 | 0·572 | 0·557 | 0·542 | 0·528 | 0·514 | 0·500 | 0·487 | 0·474 | 0·461 | 15 |
| 16 | 0·603 | 0·587 | 0·572 | 0·557 | 0·542 | 0·528 | 0·515 | 0·501 | 0·488 | 0·475 | 0·462 | 0·449 | 16 |
| 17 | 0·586 | 0·571 | 0·557 | 0·542 | 0·528 | 0·515 | 0·501 | 0·488 | 0·475 | 0·463 | 0·450 | 0·438 | 17 |
| 18 | 0·571 | 0·556 | 0·542 | 0·528 | 0·515 | 0·501 | 0·488 | 0·475 | 0·463 | 0·451 | 0·438 | 0·426 | 18 |
| 19 | 0·555 | 0·541 | 0·527 | 0·514 | 0·501 | 0·488 | 0·475 | 0·463 | 0·451 | 0·439 | 0·427 | 0·415 | 19 |
| 20 | 0·540 | 0·527 | 0·513 | 0·500 | 0·488 | 0·475 | 0·463 | 0·451 | 0·439 | 0·427 | 0·416 | 0·404 | 20 |
| 21 | 0·525 | 0·512 | 0·499 | 0·487 | 0·475 | 0·462 | 0·451 | 0·439 | 0·427 | 0·416 | 0·405 | 0·393 | 21 |
| 22 | 0·511 | 0·498 | 0·486 | 0·474 | 0·462 | 0·450 | 0·438 | 0·427 | 0·416 | 0·405 | 0·394 | 0·383 | 22 |
| 23 | 0·497 | 0·485 | 0·472 | 0·461 | 0·449 | 0·438 | 0·426 | 0·415 | 0·404 | 0·393 | 0·383 | 0·372 | 23 |
| 24 | 0·483 | 0·471 | 0·459 | 0·448 | 0·437 | 0·425 | 0·414 | 0·404 | 0·393 | 0·382 | 0·372 | 0·362 | 24 |
| 25 | 0·469 | 0·458 | 0·446 | 0·435 | 0·424 | 0·413 | 0·403 | 0·392 | 0·382 | 0·372 | 0·361 | 0·351 | 25 |
| 26 | 0·456 | 0·445 | 0·434 | 0·423 | 0·412 | 0·402 | 0·391 | 0·381 | 0·371 | 0·361 | 0·351 | 0·341 | 26 |
| 27 | 0·442 | 0·432 | 0·421 | 0·410 | 0·400 | 0·390 | 0·380 | 0·370 | 0·360 | 0·350 | 0·340 | 0·331 | 27 |
| 28 | 0·429 | 0·419 | 0·408 | 0·398 | 0·388 | 0·378 | 0·368 | 0·359 | 0·349 | 0·339 | 0·330 | 0·320 | 28 |
| 29 | 0·416 | 0·406 | 0·396 | 0·386 | 0·376 | 0·367 | 0·357 | 0·347 | 0·338 | 0·329 | 0·320 | 0·310 | 29 |
| 30 | 0·403 | 0·394 | 0·384 | 0·374 | 0·364 | 0·355 | 0·346 | 0·336 | 0·327 | 0·318 | 0·309 | 0·300 | 30 |
| 31 | 0·391 | 0·381 | 0·372 | 0·362 | 0·353 | 0·344 | 0·335 | 0·326 | 0·317 | 0·308 | 0·299 | 0·290 | 31 |
| 32 | 0·378 | 0·369 | 0·359 | 0·350 | 0·341 | 0·332 | 0·323 | 0·315 | 0·306 | 0·297 | 0·289 | 0·280 | 32 |
| 33 | 0·366 | 0·356 | 0·347 | 0·338 | 0·330 | 0·321 | 0·312 | 0·304 | 0·295 | 0·287 | 0·278 | 0·270 | 33 |
| 34 | 0·353 | 0·344 | 0·335 | 0·327 | 0·318 | 0·310 | 0·301 | 0·293 | 0·285 | 0·276 | 0·268 | 0·260 | 34 |
| 35 | 0·341 | 0·332 | 0·324 | 0·315 | 0·307 | 0·298 | 0·290 | 0·282 | 0·274 | 0·266 | 0·258 | 0·250 | 35 |
| 36 | 0·328 | 0·320 | 0·312 | 0·303 | 0·295 | 0·287 | 0·279 | 0·271 | 0·263 | 0·256 | 0·248 | 0 240 | 36 |
| 37 | 0·316 | 0·308 | 0·300 | 0·292 | 0·284 | 0·276 | 0·268 | 0·260 | 0·253 | 0·245 | 0·237 | 0·230 | 37 |
| 38 | 0·304 | 0·296 | 0·288 | 0·280 | 0·272 | 0·265 | 0·257 | 0·250 | 0·242 | 0·235 | 0·227 | 0·220 | 38 |
| 39 | 0·291 | 0·284 | 0·276 | 0·269 | 0·261 | 0·254 | 0·246 | 0·239 | 0·231 | 0·224 | 0·217 | 0·210 | 39 |
| 40 | 0·279 | 0·272 | 0·264 | 0·257 | 0·250 | 0·242 | 0·235 | 0·228 | 0·221 | 0·214 | 0·207 | 0·199 | 40 |
| 41 | 0·267 | 0·260 | 0·252 | 0·245 | 0·238 | 0·231 | 0·224 | 0·217 | 0·210 | 0·203 | 0·196 | 0·188 | 41 |
| 42 | 0·255 | 0·247 | 0·240 | 0·233 | 0·227 | 0·220 | 0·213 | 0·206 | 0·199 | 0·192 | 0·186 | 0·178 | 42 |
| 43 | 0·242 | 0·235 | 0·228 | 0·222 | 0·215 | 0·208 | 0·202 | 0·195 | 0·188 | 0·182 | 0·175 | 0·168 | 43 |
| 44 | 0·230 | 0·223 | 0·216 | 0·210 | 0·203 | 0·197 | 0·190 | 0·184 | 0·177 | 0·171 | 0·164 | 0·158 | 44 |
| 45 | 0·217 | 0·211 | 0·204 | 0·198 | 0·192 | 0·185 | 0·179 | 0·173 | 0·166 | 0·160 | 0·154 | 0·147 | 45 |
| 46 | 0·205 | 0·198 | 0·192 | 0·186 | 0·180 | 0·174 | 0·167 | 0·161 | 0·155 | 0·149 | 0·143 | 0·136 | 46 |
| 47 | 0·192 | 0·186 | 0·180 | 0·174 | 0·168 | 0·162 | 0·156 | 0·150 | 0·144 | 0·138 | 0·132 | 0·126 | 47 |
| 48 | 0·179 | 0·173 | 0·168 | 0·162 | 0·156 | 0·150 | 0·144 | 0·138 | 0·132 | 0·127 | 0·121 | 0·115 | 48 |
| 49 | 0·167 | 0·161 | 0·155 | 0·149 | 0·144 | 0·138 | 0·132 | 0·126 | 0·121 | 0·115 | 0·109 | 0·104 | 49 |
| 50 | 0·154 | 0·148 | 0·142 | 0·137 | 0·131 | 0·126 | 0·120 | 0·115 | 0·109 | 0·104 | 0·098 | 0·093 | 50 |
| 51 | 0·140 | 0·135 | 0·130 | 0·124 | 0·119 | 0·113 | 0·108 | 0·103 | 0·097 | 0·092 | 0·086 | 0·081 | 51 |
| 52 | 0·127 | 0·122 | 0·117 | 0·111 | 0·106 | 0·101 | 0·096 | 0·090 | 0·085 | 0·080 | 0·075 | 0·069 | 52 |
| 53 | 0·114 | 0·108 | 0·103 | 0·098 | 0·093 | 0·088 | 0·083 | 0·078 | 0·073 | 0·068 | 0·063 | 0·058 | 53 |
| 54 | 0·100 | 0·095 | 0·090 | 0·085 | 0·080 | 0·075 | 0·070 | 0·065 | 0·060 | 0·055 | 0·051 | 0·046 | 54 |
| 55 | 0·086 | 0·081 | 0·076 | 0·072 | 0·067 | 0·062 | 0·057 | 0·052 | 0·048 | 0·043 | 0·038 | 0·033 | 55 |
| 56 | 0·072 | 0·067 | 0·063 | 0·058 | 0·053 | 0·049 | 0·044 | 0·039 | 0·035 | 0·030 | 0·025 | 0·021 | 56 |
| 57 | 0·057 | 0·053 | 0·048 | 0·044 | 0·039 | 0·035 | 0·030 | 0·026 | 0·021 | 0·017 | 0·012 | 0·008 | 57 |
| 58 | 0·043 | 0·038 | 0·034 | 0·030 | 0·025 | 0·021 | 0·017 | 0·013 | 0·008 | 0·003 | 9·999 | 9·995 | 58 |
| 59 | 0·028 | 0·023 | 0·019 | 0·015 | 0·011 | 0·007 | 0·002 | 9·998 | 9·994 | 9·990 | 9·985 | 9·981 | 59 |
| 60 | 0·012 | 0·008 | 0·004 | 0·000 | 9·996 | 9·992 | 9·988 | 9·984 | 9·980 | 9·976 | 9·971 | 9·967 | 60 |
| 61 | 9·996 | 9·992 | 9·989 | 9·985 | 9·981 | 9·977 | 9·973 | 9·969 | 9·965 | 9·961 | 9·957 | 9·953 | 61 |
| 62 | 9·980 | 9·976 | 9·973 | 9·969 | 9·965 | 9·961 | 9·957 | 9·954 | 9·950 | 9·946 | 9·942 | 9·938 | 62 |

## LOGARITHMS OF THE CHANGE OF ALTITUDE IN ONE MINUTE OF TIME.

DIFFERENCE OF ALTITUDES FOR ONE MINUTE OF TIME.

| ″ | 0′ | 1′ | 2′ | 3′ | 4′ | 5′ | 6′ | ″ |
|---|---|---|---|---|---|---|---|---|
| 0 | | 8·82391 | 9·12494 | 9·30103 | 9·42597 | 9·52288 | 9·60206 | 0 |
| 1 | 6·04578 | 83109 | 12854 | 30343 | 42777 | 52432 | 60396 | 1 |
| 2 | 7·33679 | 83815 | 13212 | 30583 | 42957 | 52576 | 60446 | 2 |
| 3 | 52288 | 84510 | 13566 | 30821 | 43136 | 52720 | 60566 | 3 |
| 4 | 64782 | 85194 | 13918 | 31057 | 43315 | 52863 | 60686 | 4 |
| 5 | 74473 | 85867 | 14267 | 31293 | 43592 | 53006 | 60805 | 5 |
| 6 | 82391 | 86530 | 14613 | 31527 | 43669 | 53148 | 60924 | 6 |
| 7 | 89085 | 87183 | 15056 | 31760 | 43845 | 53289 | 61042 | 7 |
| 8 | 94885 | 87827 | 15397 | 31991 | 44021 | 53431 | 61160 | 8 |
| 9 | 8·00000 | 88461 | 15635 | 32222 | 44196 | 53571 | 61278 | 9 |
| 10 | 04578 | 89085 | 15970 | 32451 | 44370 | 53712 | 61396 | 10 |
| 11 | 8·08715 | 8·89701 | 9·16303 | 9·32679 | 9·44543 | 9 53852 | 9 61513 | 11 |
| 12 | 12494 | 90309 | 16633 | 32906 | 44716 | 53991 | 61630 | 12 |
| 13 | 15970 | 90908 | 16961 | 33131 | 44888 | 54130 | 61747 | 13 |
| 14 | 19188 | 91499 | 17286 | 33356 | 45059 | 54269 | 61863 | 14 |
| 15 | 22185 | 92082 | 17609 | 33579 | 45239 | 54407 | 61949 | 15 |
| 16 | 24988 | 92657 | 17930 | 33801 | 45400 | 54544 | 62094 | 16 |
| 17 | 27621 | 93225 | 18248 | 34022 | 45569 | 54682 | 62110 | 17 |
| 18 | 30103 | 93785 | 18564 | 34242 | 45738 | 54818 | 62325 | 18 |
| 19 | 32451 | 94338 | 18877 | 34461 | 45906 | 54955 | 62448 | 19 |
| 20 | 34679 | 94885 | 19188 | 34679 | 46073 | 55091 | 62554 | 20 |
| 21 | 8·36798 | 8·95424 | 9·19498 | 9·34995 | 9·46240 | 9 55226 | 9 62668 | 21 |
| 22 | 38818 | 95957 | 19804 | 35111 | 46406 | 55361 | 62782 | 22 |
| 23 | 40748 | 96483 | 20009 | 35325 | 46571 | 55496 | 62896 | 23 |
| 24 | 42597 | 97004 | 20412 | 35539 | 46724 | 55630 | 63009 | 24 |
| 25 | 44370 | 97518 | 20712 | 35751 | 46900 | 55764 | 63122 | 25 |
| 26 | 46073 | 98025 | 21011 | 35962 | 47064 | 55897 | 63234 | 26 |
| 27 | 47712 | 98528 | 21307 | 36173 | 47227 | 56030 | 63347 | 27 |
| 28 | 49291 | 99024 | 21602 | 36482 | 47389 | 56163 | 63459 | 28 |
| 29 | 50815 | 99515 | 21894 | 36590 | 47551 | 56295 | 63571 | 29 |
| 30 | 52288 | 9·00000 | 22185 | 36798 | 47712 | 56427 | 63682 | 30 |
| 31 | 8·53712 | 9·00480 | 9·22473 | 9·37004 | 9·47873 | 9·56558 | 9·63793 | 31 |
| 32 | 55091 | 00954 | 22760 | 37209 | 48033 | 56689 | 63904 | 32 |
| 33 | 56427 | 01424 | 23045 | 37414 | 48192 | 56820 | 64015 | 33 |
| 34 | 57724 | 01988 | 23328 | 37617 | 48351 | 56950 | 64125 | 34 |
| 35 | 58982 | 02348 | 23609 | 37819 | 48509 | 57080 | 64235 | 35 |
| 36 | 60206 | 02803 | 23888 | 38021 | 48667 | 57210 | 64345 | 36 |
| 37 | 61396 | 03253 | 24166 | 38222 | 48824 | 57339 | 64455 | 37 |
| 38 | 62554 | 03698 | 24441 | 38421 | 48980 | 57467 | 64564 | 38 |
| 39 | 63682 | 04139 | 24715 | 38620 | 49136 | 57696 | 64673 | 39 |
| 40 | 64782 | 04578 | 24988 | 38818 | 49291 | 57724 | 64782 | 40 |
| 41 | 8·65854 | 9·05008 | 9·25258 | 9·39015 | 9·49446 | 9·57851 | 9·64890 | 41 |
| 42 | 66901 | 05536 | 25527 | 39211 | 49601 | 57978 | 64998 | 42 |
| 43 | 67922 | 05858 | 25794 | 39406 | 49754 | 58108 | 65106 | 43 |
| 44 | 68921 | 06279 | 26060 | 39600 | 49907 | 58231 | 65214 | 44 |
| 45 | 69897 | 06695 | 26324 | 39794 | 50030 | 58358 | 65321 | 45 |
| 46 | 70851 | 07106 | 26586 | 39986 | 50212 | 58483 | 65428 | 46 |
| 47 | 71785 | 07514 | 26847 | 40178 | 50364 | 58609 | 65535 | 47 |
| 48 | 72700 | 07918 | 27107 | 40369 | 50515 | 58734 | 65642 | 48 |
| 49 | 73595 | 08318 | 27364 | 40559 | 50665 | 58858 | 65748 | 49 |
| 50 | 74473 | 08715 | 27621 | 40748 | 50815 | 58982 | 65854 | 50 |
| 51 | 8·75333 | 9·09108 | 9·27875 | 9·40937 | 9·50965 | 9 59106 | 9·65960 | 51 |
| 52 | 76176 | 09497 | 28128 | 41124 | 51114 | 59230 | 66065 | 52 |
| 53 | 77003 | 09883 | 28380 | 41311 | 51262 | 59363 | 66171 | 53 |
| 54 | 77815 | 10266 | 28631 | 41497 | 51410 | 59476 | 66276 | 54 |
| 55 | 78612 | 10665 | 28879 | 41682 | 51558 | 59598 | 66380 | 55 |
| 56 | 79394 | 11021 | 29127 | 41967 | 51705 | 59721 | 66485 | 56 |
| 57 | 80163 | 11394 | 29373 | 42050 | 51851 | 59842 | 66589 | 57 |
| 58 | 80918 | 11764 | 29618 | 42233 | 51997 | 59964 | 66693 | 58 |
| 59 | 81661 | 12130 | 29861 | 42415 | 52143 | 60085 | 66797 | 59 |
| ″ | 0′ | 1′ | 2′ | 3′ | 4′ | 5′ | 6′ | ″ |

## LOGARITHMS OF THE CHANGE OF ALTITUDE IN ONE MINUTE OF TIME.

DIFFERENCE OF ALTITUDES FOR ONE MINUTE OF TIME.

| ″ | 7′ | 8′ | 9′ | 10′ | 11′ | 12′ | 13′ | 14′ | ″ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 9·66901 | 9·72700 | 9·77815 | 9·82391 | 9·86530 | 9·90309 | 9·93785 | 9·96004 | 0 |
| 1 | 67004 | 72790 | 77895 | 82463 | 86596 | 90371 | 93841 | 97055 | 1 |
| 2 | 67107 | 72880 | 77976 | 82535 | 86661 | 90429 | 93891 | 97107 | 2 |
| 3 | 67210 | 72970 | 78056 | 82607 | 86727 | 90489 | 93952 | 97158 | 3 |
| 4 | 67312 | 73060 | 78135 | 82679 | 86792 | 90549 | 94007 | 97210 | 4 |
| 5 | 67413 | 73150 | 78216 | 82751 | 86858 | 90609 | 94063 | 97261 | 5 |
| 6 | 67517 | 73239 | 78295 | 82823 | 86923 | 90669 | 94118 | 97313 | 6 |
| 7 | 67618 | 73329 | 78374 | 82894 | 86988 | 90729 | 94173 | 97364 | 7 |
| 8 | 67720 | 73418 | 78454 | 82966 | 87053 | 90789 | 94228 | 97415 | 8 |
| 9 | 67821 | 73507 | 78533 | 83037 | 87118 | 90848 | 94283 | 97466 | 9 |
| 10 | 67922 | 73595 | 78612 | 83109 | 87183 | 90908 | 94338 | 97518 | 10 |
| 11 | 9·68023 | 9·73684 | 9·78691 | 9·83180 | 9·87248 | 9·90967 | 9·94393 | 9·97569 | 11 |
| 12 | 68124 | 73772 | 78770 | 83251 | 87313 | 91027 | 94448 | 97620 | 12 |
| 13 | 68224 | 73868 | 78848 | 83322 | 87377 | 91086 | 94503 | 97671 | 13 |
| 14 | 68325 | 73948 | 78927 | 83392 | 87442 | 91155 | 94558 | 97721 | 14 |
| 15 | 68425 | 74036 | 79005 | 83463 | 87506 | 91204 | 94612 | 97772 | 15 |
| 16 | 68524 | 74124 | 79083 | 83534 | 87570 | 91263 | 94667 | 97823 | 16 |
| 17 | 68624 | 74211 | 79161 | 83604 | 87634 | 91322 | 94721 | 97874 | 17 |
| 18 | 68723 | 74299 | 79239 | 83674 | 87699 | 91381 | 94776 | 97924 | 18 |
| 19 | 68822 | 74386 | 79317 | 83745 | 87763 | 91440 | 94830 | 97975 | 19 |
| 20 | 68921 | 74473 | 79394 | 83815 | 87827 | 91499 | 94885 | 98025 | 20 |
| 21 | 9·69019 | 9·74559 | 9·79472 | 9·83885 | 9·87890 | 9·91557 | 9·94939 | 9·98076 | 21 |
| 22 | 69118 | 74646 | 79549 | 83955 | 87954 | 91616 | 94993 | 98126 | 22 |
| 23 | 69216 | 74732 | 79626 | 84024 | 88018 | 91675 | 95047 | 98177 | 23 |
| 24 | 69314 | 74819 | 79703 | 84094 | 88081 | 91733 | 95101 | 98227 | 24 |
| 25 | 69412 | 74905 | 79780 | 84164 | 88145 | 91791 | 95155 | 98277 | 25 |
| 26 | 69509 | 74991 | 79857 | 84233 | 88208 | 91850 | 95209 | 98327 | 26 |
| 27 | 69606 | 75076 | 79934 | 84302 | 88271 | 91908 | 95263 | 98378 | 27 |
| 28 | 69703 | 75162 | 80010 | 84372 | 88334 | 91966 | 95317 | 98428 | 28 |
| 29 | 69800 | 75247 | 80087 | 84441 | 88398 | 92024 | 95370 | 98478 | 29 |
| 30 | 69897 | 75333 | 80163 | 84510 | 88461 | 92082 | 95424 | 98528 | 30 |
| 31 | 9·69993 | 9·75418 | 9·80239 | 9·84579 | 9·88523 | 9·92140 | 9·95478 | 9·98577 | 31 |
| 32 | 70089 | 75503 | 80315 | 84647 | 88586 | 92197 | 95531 | 98627 | 32 |
| 33 | 70185 | 75587 | 80391 | 84716 | 88649 | 92265 | 95585 | 98677 | 33 |
| 34 | 70281 | 75672 | 80467 | 84785 | 88712 | 92313 | 95638 | 98727 | 34 |
| 35 | 70377 | 75756 | 80542 | 84853 | 88774 | 92370 | 95691 | 98776 | 35 |
| 36 | 70472 | 75841 | 80618 | 84921 | 88837 | 92428 | 95745 | 98826 | 36 |
| 37 | 70567 | 75925 | 80693 | 84990 | 88899 | 92485 | 95798 | 98876 | 37 |
| 38 | 70662 | 76009 | 80768 | 85058 | 88961 | 92543 | 95851 | 98925 | 38 |
| 39 | 70757 | 76092 | 80843 | 85126 | 89023 | 92600 | 95904 | 98975 | 39 |
| 40 | 70851 | 76176 | 80918 | 85194 | 89085 | 92657 | 95957 | 99024 | 40 |
| 41 | 9·70946 | 9·76259 | 9·80993 | 9·85261 | 9·89147 | 9·92714 | 9·96010 | 9·99073 | 41 |
| 42 | 71040 | 76343 | 81068 | 85329 | 89209 | 92771 | 96063 | 99122 | 42 |
| 43 | 71134 | 76426 | 81142 | 85397 | 89271 | 92828 | 96116 | 99172 | 43 |
| 44 | 71227 | 76509 | 81217 | 85464 | 89333 | 92885 | 96168 | 99221 | 44 |
| 45 | 71321 | 76592 | 81291 | 85532 | 89395 | 92942 | 96221 | 99270 | 45 |
| 46 | 71414 | 76674 | 81365 | 85599 | 89456 | 92999 | 96274 | 99319 | 46 |
| 47 | 71507 | 76757 | 81439 | 85666 | 89518 | 93053 | 96326 | 99368 | 47 |
| 48 | 71600 | 76839 | 81513 | 85733 | 89579 | 93112 | 96379 | 99417 | 48 |
| 49 | 71693 | 76921 | 81587 | 85800 | 89640 | 93168 | 96431 | 99466 | 49 |
| 50 | 71785 | 77003 | 81661 | 85867 | 89701 | 93225 | 96483 | 99515 | 50 |
| 51 | 9·71878 | 9·77085 | 9·81734 | 9·85934 | 9·89763 | 9·93281 | 9·96536 | 9·99563 | 51 |
| 52 | 71970 | 77167 | 81808 | 86000 | 89824 | 93337 | 96588 | 99612 | 52 |
| 53 | 72062 | 77248 | 81881 | 86067 | 89885 | 93394 | 96640 | 99661 | 53 |
| 54 | 72163 | 77330 | 81954 | 86133 | 89945 | 93450 | 96692 | 99709 | 54 |
| 55 | 72245 | 77411 | 82027 | 86200 | 90006 | 93506 | 96744 | 99758 | 55 |
| 56 | 72336 | 77492 | 82100 | 86266 | 90067 | 93562 | 96796 | 99806 | 56 |
| 57 | 72427 | 77573 | 82173 | 86332 | 90128 | 93618 | 96848 | 99855 | 57 |
| 58 | 72518 | 77654 | 82246 | 86398 | 90188 | 93674 | 96900 | 99903 | 58 |
| 59 | 72609 | 77738 | 82318 | 86464 | 90249 | 93729 | 96952 | 99952 | 59 |
| ″ | 7′ | 8′ | 9′ | 10′ | 11′ | 12′ | 13′ | 14′ | ″ |

## SINE SQUARE.

0 HOUR.

| M. | 0ˢ | 5ˢ | 10ˢ | 15ˢ | 20ˢ | 25ˢ | 30ˢ | 35ˢ | 40ˢ | 45ˢ | 50ˢ | 55ˢ | M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 3·519 | 3·121 | 3 473 | 3·723 | 3·917 | 4·076 | 4·209 | 4 325 | 4·428 | 4·519 | 4·602 | 0 |
| 1 | 4·678 | 4·747 | 4 811 | 4 871 | 4·927 | 4 980 | 5·030 | 5 078 | 5 121 | 5 164 | 5 204 | 5·243 | 1 |
| 2 | 5·280 | 5·315 | 5 349 | 5 382 | 5·414 | 5·444 | 5·463 | 5 502 | 5 530 | 5 556 | 5 582 | 5 607 | 2 |
| 3 | 5·632 | 5 656 | 5·679 | 5·701 | 5 723 | 5 745 | 5·766 | 5·786 | 5 806 | 5 826 | 5 845 | 5 863 | 3 |
| 4 | 5·882 | 5 900 | 5·917 | 5 934 | 5 951 | 5 968 | 5 984 | 6·000 | 6 016 | 6 031 | 6 046 | 6 061 | 4 |
| 5 | 6·076 | 6·090 | 6·104 | 6 118 | 6 132 | 6 145 | 6 158 | 6·171 | 6·184 | 6 197 | 6 209 | 6·222 | 5 |
| 6 | 6·234 | 6·246 | 6·258 | 6 269 | 6·281 | 6·292 | 6 303 | 6·314 | 6·325 | 6 336 | 6 347 | 6·357 | 6 |
| 7 | 6·368 | 6·378 | 6·388 | 6 398 | 6·408 | 6·418 | 6 428 | 6·437 | 6·447 | 6·456 | 6 465 | 6·475 | 7 |
| 8 | 6·484 | 6·493 | 6·502 | 6 510 | 6 519 | 6 528 | 6 536 | 6·545 | 6·553 | 6 562 | 6 570 | 6 578 | 8 |
| 9 | 6·586 | 6·594 | 6 602 | 6 610 | 6 618 | 6 625 | 6 633 | 6 641 | 6·648 | 6 656 | 6 663 | 6 670 | 9 |
| 10 | 6·678 | 6·685 | 6 692 | 6 699 | 6·706 | 6·713 | 6 720 | 6·727 | 6·734 | 6 740 | 6 747 | 6·754 | 10 |
| 11 | 6·760 | 6 767 | 6·773 | 6 780 | 6·786 | 6·793 | 6·799 | 6 805 | 6·811 | 6·818 | 6 824 | 6·830 | 11 |
| 12 | 6·836 | 6·842 | 6 848 | 6 854 | 6 860 | 6·865 | 6·872 | 6·877 | 6·883 | 6·888 | 6 894 | 6·900 | 12 |
| 13 | 6·905 | 6·911 | 6·916 | 6·922 | 6·927 | 6 933 | 6·938 | 6·943 | 6·949 | 6·954 | 6 959 | 6 965 | 13 |
| 14 | 6·970 | 6 975 | 6 980 | 6 985 | 6 990 | 6 995 | 7·000 | 7·005 | 7·010 | 7·015 | 7·020 | 7·025 | 14 |
| 15 | 7·030 | 7·034 | 7·039 | 7·044 | 7·049 | 7·053 | 7·058 | 7·063 | 7·067 | 7·072 | 7·077 | 7·081 | 15 |
| 16 | 7·086 | 7·090 | 7·095 | 7·099 | 7·104 | 7·108 | 7·112 | 7·117 | 7·121 | 7·125 | 7·130 | 7·134 | 16 |
| 17 | 7·138 | 7·143 | 7·147 | 7·151 | 7·155 | 7·159 | 7·163 | 7·168 | 7·172 | 7·176 | 7·180 | 7·184 | 17 |
| 18 | 7·188 | 7·192 | 7·196 | 7·200 | 7·204 | 7·208 | 7·212 | 7·216 | 7·219 | 7·223 | 7·227 | 7·231 | 18 |
| 19 | 7·235 | 7·239 | 7·242 | 7·246 | 7·250 | 7·254 | 7·257 | 7·261 | 7·265 | 7·268 | 7·272 | 7·276 | 19 |
| 20 | 7·279 | 7·283 | 7·287 | 7·290 | 7·294 | 7·297 | 7·301 | 7·304 | 7·308 | 7·311 | 7·315 | 7·318 | 20 |
| 21 | 7·322 | 7·325 | 7·329 | 7·332 | 7·335 | 7·339 | 7·342 | 7·345 | 7·349 | 7·352 | 7·355 | 7·359 | 21 |
| 22 | 7·362 | 7·365 | 7·369 | 7·372 | 7·375 | 7·378 | 7·382 | 7·385 | 7·388 | 7·391 | 7·394 | 7·398 | 22 |
| 23 | 7·401 | 7·404 | 7·407 | 7·410 | 7·413 | 7·416 | 7·419 | 7·422 | 7·425 | 7·429 | 7·432 | 7·435 | 23 |
| 24 | 7·438 | 7·441 | 7·444 | 7·447 | 7·450 | 7·453 | 7·455 | 7·458 | 7·461 | 7·464 | 7·467 | 7·470 | 24 |
| 25 | 7·473 | 7·476 | 7·479 | 7·482 | 7·485 | 7·487 | 7·490 | 7·493 | 7·496 | 7·499 | 7·501 | 7·504 | 25 |
| 26 | 7·507 | 7·510 | 7·513 | 7·515 | 7·518 | 7·521 | 7·524 | 7·526 | 7·529 | 7·532 | 7·534 | 7·537 | 26 |
| 27 | 7·540 | 7·542 | 7·545 | 7·548 | 7·550 | 7·553 | 7·556 | 7·558 | 7·561 | 7·564 | 7·566 | 7·569 | 27 |
| 28 | 7·571 | 7·574 | 7·577 | 7·579 | 7·582 | 7·584 | 7·587 | 7·589 | 7·592 | 7·594 | 7·597 | 7·599 | 28 |
| 29 | 7·602 | 7·604 | 7·607 | 7·609 | 7·612 | 7·614 | 7·617 | 7·619 | 7·622 | 7·624 | 7·626 | 7·628 | 29 |
| 30 | 7·631 | 7·634 | 7·636 | 7·638 | 7·641 | 7·643 | 7·646 | 7·648 | 7·650 | 7·653 | 7·655 | 7·657 | 30 |
| 31 | 7·660 | 7·662 | 7·664 | 7·667 | 7·669 | 7·671 | 7·674 | 7·676 | 7·678 | 7·680 | 7·683 | 7·685 | 31 |
| 32 | 7·687 | 7·689 | 7·692 | 7·694 | 7·696 | 7·698 | 7·701 | 7·703 | 7·705 | 7·707 | 7·709 | 7·712 | 32 |
| 33 | 7·714 | 7·716 | 7·718 | 7·720 | 7·723 | 7·725 | 7·727 | 7·729 | 7·731 | 7·733 | 7·735 | 7·738 | 33 |
| 34 | 7·740 | 7·742 | 7·744 | 7·746 | 7·748 | 7·750 | 7·752 | 7·754 | 7·757 | 7·759 | 7·761 | 7·763 | 34 |
| 35 | 7·765 | 7·767 | 7·769 | 7·771 | 7·773 | 7·775 | 7·777 | 7·779 | 7·781 | 7·783 | 7·785 | 7·787 | 35 |
| 36 | 7·789 | 7·791 | 7·793 | 7·795 | 7·797 | 7·799 | 7·801 | 7·803 | 7·805 | 7·807 | 7·809 | 7·811 | 36 |
| 37 | 7·813 | 7·815 | 7·817 | 7·819 | 7·821 | 7·823 | 7·825 | 7·827 | 7·829 | 7·830 | 7·832 | 7·834 | 37 |
| 38 | 7·836 | 7·838 | 7·840 | 7·842 | 7·844 | 7·846 | 7·847 | 7·849 | 7·851 | 7·853 | 7·855 | 7·857 | 38 |
| 39 | 7·859 | 7·861 | 7·862 | 7·864 | 7·866 | 7·868 | 7·870 | 7·872 | 7·873 | 7·875 | 7·877 | 7·879 | 39 |
| 40 | 7·881 | 7·882 | 7·884 | 7·886 | 7·888 | 7·890 | 7 891 | 7·893 | 7·895 | 7·897 | 7·898 | 7·900 | 40 |
| 41 | 7·902 | 7·904 | 7·906 | 7·907 | 7·909 | 7·911 | 7·912 | 7·914 | 7·916 | 7·918 | 7·919 | 7·921 | 41 |
| 42 | 7·923 | 7·925 | 7·926 | 7·928 | 7·930 | 7·931 | 7·933 | 7·935 | 7·937 | 7·938 | 7·940 | 7·942 | 42 |
| 43 | 7·943 | 7·945 | 7·947 | 7·948 | 7·950 | 7·952 | 7·953 | 7·955 | 7·957 | 7·958 | 7·960 | 7·962 | 43 |
| 44 | 7·963 | 7·965 | 7·966 | 7·968 | 7·970 | 7·971 | 7·973 | 7·975 | 7·976 | 7·978 | 7·979 | 7·981 | 44 |
| 45 | 7·983 | 7·984 | 7·986 | 7·987 | 7·989 | 7·991 | 7·992 | 7·994 | 7·995 | 7·997 | 7·998 | 8·000 | 45 |
| 46 | 8·002 | 8·003 | 8·005 | 8·006 | 8·008 | 8·009 | 8·011 | 8·013 | 8·014 | 8·016 | 8·017 | 8·019 | 46 |
| 47 | 8·020 | 8·022 | 8·023 | 8·025 | 8·026 | 8·028 | 8·029 | 8·031 | 8·032 | 8·034 | 8·035 | 8·037 | 47 |
| 48 | 8·038 | 8·040 | 8·041 | 8·043 | 8·044 | 8·046 | 8·047 | 8·049 | 8·050 | 8·052 | 8·053 | 8·055 | 48 |
| 49 | 8·056 | 8·058 | 8·059 | 8·061 | 8·062 | 8·064 | 8·065 | 8·067 | 8·068 | 8·069 | 8·071 | 8·072 | 49 |
| 50 | 8·074 | 8·075 | 8·077 | 8·078 | 8·080 | 8·081 | 8·082 | 8·084 | 8·085 | 8·087 | 8·088 | 8·090 | 50 |
| 51 | 8·091 | 8·092 | 8·094 | 8·095 | 8·097 | 8·098 | 8·099 | 8·101 | 8·102 | 8·104 | 8·105 | 8·106 | 51 |
| 52 | 8·108 | 8·109 | 8·110 | 8·112 | 8·113 | 8·115 | 8·116 | 8·117 | 8·119 | 8·120 | 8·121 | 8·123 | 52 |
| 53 | 8·124 | 8·126 | 8·127 | 8·128 | 8·130 | 8·131 | 8·132 | 8·134 | 8·135 | 8·136 | 8·138 | 8·139 | 53 |
| 54 | 8·140 | 8·142 | 8·143 | 8·144 | 8·146 | 8·147 | 8·148 | 8·150 | 8·151 | 8·152 | 8·154 | 8·155 | 54 |
| 55 | 8·156 | 8·158 | 8·159 | 8·160 | 8·161 | 8·163 | 8·164 | 8·165 | 8·167 | 8·168 | 8·169 | 8·171 | 55 |
| 56 | 8·172 | 8·173 | 8·174 | 8·176 | 8·177 | 8·178 | 8·179 | 8·181 | 8·182 | 8·183 | 8·185 | 8·186 | 56 |
| 57 | 8·187 | 8·188 | 8·190 | 8·191 | 8·192 | 8·193 | 8·195 | 8·196 | 8·197 | 8·198 | 8·200 | 8·201 | 57 |
| 58 | 8·202 | 8·203 | 8·205 | 8·206 | 8·207 | 8·208 | 8·210 | 8·211 | 8·212 | 8·213 | 8·214 | 8·216 | 58 |
| 59 | 8·217 | 8·218 | 8·219 | 8·221 | 8·222 | 8·223 | 8·224 | 8·225 | 8·227 | 8·228 | 8·229 | 8·230 | 59 |

## EQUATIONS OF EQUAL ALTITUDES.

| Elapsed Time. | 2h | | 3h | | 4h | | 5h | | 6h | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + |
| 0m | 9·4109 | 9·3959 | 9·4172 | 9·3828 | 9·4260 | 9·3635 | 9·4374 | 9·3369 | 9·4515 | 9·3010 |
| 2 | 9·4111 | 9·3955 | 9·4174 | 9 3822 | 9·4263 | 9·3627 | 9·4378 | 9·3358 | 9·4521 | 9·2996 |
| 4 | 9 4113 | 9·3952 | 9·4177 | 9·3817 | 9 4266 | 9·3620 | 9·4383 | 9·3348 | 9·4526 | 9·2982 |
| 6 | 9 4114 | 9·3948 | 9·4179 | 9·3811 | 9·4270 | 9·3612 | 9·4387 | 9·3337 | 9·4531 | 9·2968 |
| 8 | 9·4116 | 9·3944 | 9·4182 | 9 3806 | 9·4273 | 9·3604 | 9·4391 | 9·3327 | 9·4536 | 9·2954 |
| 10 | 9·4118 | 9·3941 | 9 4184 | 9 3800 | 9·4277 | 9·3596 | 9·4396 | 9·3316 | 9·4542 | 9·2940 |
| 12 | 9·4120 | 9·3937 | 9·4187 | 9 3794 | 9·4280 | 9·3588 | 9·4400 | 9·3305 | 9·4547 | 9·2925 |
| 14 | 9·4121 | 9·3933 | 9·4190 | 9·3789 | 9·4284 | 9·3580 | 9·4405 | 9·3294 | 9·4552 | 9·2911 |
| 16 | 9·4123 | 9·3929 | 9·4193 | 9·3783 | 9·4288 | 9·3572 | 9·4409 | 9·3283 | 9·4558 | 9·2896 |
| 18 | 9·4125 | 9·3925 | 9·4195 | 9·3777 | 9·4291 | 9·3564 | 9·4414 | 9·3272 | 9·4563 | 9·2881 |
| 20 | 9·4127 | 9·3921 | 9·4198 | 9·3771 | 9·4295 | 9 3555 | 9·4418 | 9·3261 | 9·4569 | 9·2886 |
| 22 | 9·4129 | 9·3917 | 9·4201 | 9·3765 | 9·4299 | 9·3547 | 9·4423 | 9·3249 | 9·4574 | 9·2850 |
| 24 | 9·4131 | 9·3913 | 9·4204 | 9·3759 | 9·4302 | 9·3538 | 9·4427 | 9·3238 | 9·4580 | 9·2835 |
| 26 | 9·4133 | 9·3909 | 9·4207 | 9·3752 | 9·4306 | 9·3530 | 9·4432 | 9·3226 | 9·4585 | 9·2819 |
| 28 | 9·4135 | 9·3905 | 9·4209 | 9·3746 | 9·4310 | 9·3521 | 9·4437 | 9·3214 | 9·4591 | 9·2804 |
| 30 | 9·4137 | 9·3900 | 9·4212 | 9·3740 | 9·4314 | 9·3512 | 9·4441 | 9·3203 | 9·4597 | 9·2788 |
| 32 | 9·4139 | 9·3896 | 9·4215 | 9·3733 | 9·4317 | 9·3503 | 9·4446 | 9·3191 | 9·4602 | 9·2772 |
| 34 | 9·4141 | 9·3892 | 9·4218 | 9·3727 | 9·4321 | 9·3494 | 9·4451 | 9·3178 | 9·4608 | 9·2756 |
| 36 | 9·4144 | 9·3887 | 9·4221 | 9·3720 | 9·4325 | 9·3485 | 9·4456 | 9·3166 | 9·4614 | 9·2739 |
| 38 | 9·4146 | 9·3882 | 9·4224 | 9·3713 | 9·4329 | 9·3476 | 9·4460 | 9·3154 | 9·4620 | 9·2723 |
| 40 | 9·4148 | 9·3878 | 9·4227 | 9·3707 | 9.4333 | 9·3467 | 9·4465 | 9·3142 | 9·4625 | 9·2706 |
| 42 | 9·4150 | 9·3873 | 9·4231 | 9·3700 | 9·4337 | 9·3457 | 9·4470 | 9·3129 | 9·4631 | 9·2689 |
| 44 | 9·4152 | 9·3868 | 9·4234 | 9·3693 | 9·4341 | 9·3448 | 9·4475 | 9·3116 | 9·4637 | 9·2672 |
| 46 | 9·4155 | 9·3863 | 9·4237 | 9·3686 | 9·4345 | 9·3438 | 9·4480 | 9·3103 | 9·4643 | 9·2655 |
| 48 | 9·4157 | 9·3859 | 9·4240 | 9·3679 | 9·4349 | 9·3429 | 9·4485 | 9·3091 | 9·4649 | 9 2638 |
| 50 | 9·4159 | 9·3854 | 9·4243 | 9·3672 | 9·4353 | 9·3419 | 9·4490 | 9 3078 | 9·4655 | 9·2620 |
| 52 | 9·4162 | 9·3849 | 9·4246 | 9·3665 | 9·4357 | 9·3409 | 9·4495 | 9·3064 | 9·4661 | 9·2602 |
| 54 | 9·4164 | 9·3843 | 9·4250 | 9·3657 | 9·4361 | 9·3399 | 9·4500 | 9·3051 | 9·4667 | 9·2584 |
| 56 | 9·4167 | 9·3838 | 9·4253 | 9·3650 | 9·4366 | 9·3389 | 9·4505 | 9·3038 | 9·4673 | 9·2566 |
| 58 | 9·4169 | 9·3833 | 9·4256 | 9·3643 | 9·4370 | 9·3379 | 9·4510 | 9·3024 | 9·4679 | 9·2548 |
| 60 | 9·4172 | 9·3828 | 9·4260 | 9·3635 | 9·4374 | 9·3369 | 9·4515 | 9·3010 | 9·4685 | 9·2530 |

| Elapsed Time. | 7h | | 8h | | 9h | | 10h | | 11h | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + | Log. A. — | Log. B. + |
| 0m | 9·4685 | 9·2530 | 9·4884 | 9·1874 | 9·5115 | 9·0943 | 9·5379 | 8·9509 | 9·5680 | 8·6837 |
| 2 | 9·4691 | 9·2511 | 9·4892 | 9·1848 | 9·5123 | 9·0906 | 9·5389 | 8·9447 | 9·5691 | 8·6701 |
| 4 | 9·4697 | 9·2492 | 9·4899 | 9·1822 | 9·5132 | 9·0867 | 9·5398 | 8·9384 | 9·5701 | 8·6560 |
| 6 | 9·4704 | 9·2473 | 9·4906 | 9·1796 | 9·5140 | 9·0828 | 9·5408 | 8·9320 | 9·5712 | 8·6414 |
| 8 | 9·4710 | 9·2454 | 9·4913 | 9·1769 | 9·5148 | 9·0789 | 9·5417 | 8·9254 | 9·5723 | 8·6262 |
| 10 | 9·4716 | 9·2434 | 9·4921 | 9·1742 | 9·5157 | 9·0749 | 9·5427 | 8·9187 | 9·5734 | 8·6103 |
| 12 | 9·4723 | 9·2415 | 9·4928 | 9 1715 | 9·5165 | 9·0708 | 9·5436 | 8·9118 | 9·5745 | 8·5937 |
| 14 | 9·4729 | 9·2395 | 9·4935 | 9·1687 | 9·5174 | 9·0667 | 9·5446 | 8·9048 | 9·5756 | 8·5764 |
| 16 | 9·4735 | 9·2375 | 9·4943 | 9·1659 | 9·5182 | 9·0625 | 9·5456 | 8·8977 | 9·5767 | 8·5583 |
| 18 | 9·4742 | 9·2355 | 9·4950 | 9·1630 | 9·5191 | 9·0583 | 9·5466 | 8·8904 | 9·5778 | 8·5392 |
| 20 | 9·4748 | 9·2334 | 9·4958 | 9·1602 | 9·5199 | 9·0540 | 9·5475 | 8·8829 | 9·5789 | 8·5192 |
| 22 | 9·4755 | 9·2313 | 9·4965 | 9·1573 | 9·5208 | 9·0496 | 9·5485 | 8·8752 | 9·5800 | 8·4981 |
| 24 | 9·4761 | 9·2292 | 9·4973 | 9·1543 | 9·5217 | 9·0452 | 9·5495 | 8·8674 | 9·5811 | 8·4758 |
| 26 | 9·4768 | 9·2271 | 9·4980 | 9·1513 | 9·5225 | 9·0406 | 9·5505 | 8·8594 | 9·5822 | 8·4521 |
| 28 | 9·4774 | 9·2250 | 9·4988 | 9·1483 | 9·5234 | 9·0360 | 9·5515 | 8·8511 | 9·5834 | 8·4270 |
| 30 | 9·4781 | 9·2228 | 9·4996 | 9·1453 | 9·5243 | 9·0314 | 9·5525 | 8·8427 | 9·5845 | 8·4001 |
| 32 | 9·4788 | 9·2206 | 9·5003 | 9·1422 | 9·5252 | 9·0266 | 9·5535 | 8·8341 | 9·5856 | 8·3713 |
| 34 | 9·4794 | 9·2184 | 9·5011 | 9·1390 | 9·5261 | 9·0218 | 9·5545 | 8·8252 | 9·5868 | 8·3403 |
| 36 | 9·4801 | 9·2162 | 9·5019 | 9·1359 | 9·5269 | 9·0169 | 9·5555 | 8·8162 | 9·5879 | 8·3067 |
| 38 | 9·4808 | 9·2140 | 9·5027 | 9·1327 | 9·5278 | 9·0119 | 9·5565 | 8·8068 | 9·5891 | 8·2701 |
| 40 | 9·4815 | 9·2117 | 9·5035 | 9 1294 | 9·5287 | 9·0069 | 9·5576 | 8·7972 | 9·5902 | 8·2299 |
| 42 | 9·4821 | 9·2094 | 9·5042 | 9·1261 | 9·5296 | 9·0017 | 9·5586 | 8·7874 | 9·5914 | 8·1853 |
| 44 | 9·4828 | 9·2070 | 9·5050 | 9·1228 | 9·5305 | 8·9965 | 9·5596 | 8·7772 | 9·5926 | 8·1354 |
| 46 | 9 4835 | 9·2047 | 9·5058 | 9·1194 | 9·5314 | 8·9911 | 9·5606 | 8·7668 | 9·5937 | 8·0786 |
| 48 | 9 4842 | 9·2023 | 9·5066 | 9·1159 | 9·5324 | 8·9857 | 9·5617 | 8·7560 | 9·5949 | 8·0128 |
| 50 | 9·4849 | 9·1999 | 9·5074 | 9·1125 | 9 5333 | 8·9802 | 9 5627 | 8·7449 | 9·5961 | 7 9348 |
| 52 | 9·4856 | 9·1974 | 9·5082 | 9·1089 | 9·5342 | 8·9745 | 9 5638 | 8·7335 | 9·5973 | 7·8391 |
| 54 | 9·4863 | 9·1950 | 9·5091 | 9·1054 | 9·5351 | 8·9688 | 9·5648 | 8·7217 | 9·5985 | 7·7154 |
| 56 | 9·4870 | 9·1925 | 9·5099 | 9·1017 | 9·5361 | 8·9630 | 9·5659 | 8·7094 | 9 5997 | 7 5405 |
| 58 | 9·4877 | 9·1900 | 9·5107 | 9·0981 | 9·5370 | 8·9570 | 9·5669 | 8·6968 | 9 6009 | 7·2407 |
| 60 | 9·4884 | 9·1874 | 9·5115 | 9·0943 | 9·5379 | 8·9509 | 9·5680 | 8·6837 | 9·6021 | Inf. Neg. |

## SPHERICAL TRAVERSE TABLE.

| | 0° | | 1° | | 2° | | 3° | | 4° | | 5° | | 6° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 0 | 100·0 | 0 | | | | | | | | | | | | |
| 1 | 100·0 | 0 | 100·0 | 0·0 | | | | | | | | | | |
| 2 | 100·1 | 0 | 100·1 | 0·1 | 100·1 | 0·1 | | | | | | | | |
| 3 | 100·1 | 0 | 100·1 | 0·1 | 100·2 | 0·2 | 100·3 | 0·3 | | | | | | |
| 4 | 100·2 | 0 | 100·3 | 0·1 | 100·3 | 0·2 | 100·4 | 0·4 | 100·5 | 0·5 | | | | |
| 5 | 100·4 | 0 | 100·4 | 0·1 | 100·4 | 0·3 | 100·5 | 0·5 | 100·6 | 0·6 | 100·8 | 0·8 | | |
| 6 | 100·5 | 0 | 100·6 | 0·2 | 100·6 | 0·4 | 100·7 | 0·5 | 100·8 | 0·7 | 100 9 | 0·9 | 101·1 | 1·1 |
| 7 | 100·7 | 0 | 100·8 | 0·2 | 100·8 | 0·4 | 100·9 | 0·6 | 101·0 | 0·9 | 101·1 | 1·1 | 101·3 | 1·3 |
| 8 | 101·0 | 0 | 101·0 | 0·2 | 101·0 | 0·5 | 101·1 | 0·7 | 101·2 | 1·0 | 101·4 | 1·2 | 101·5 | 1·5 |
| 9 | 101·2 | 0 | 101·3 | 0·3 | 101·3 | 0·5 | 101·4 | 0·8 | 101·5 | 1·1 | 101·6 | 1·4 | 101·8 | 1·7 |
| 10 | 101·5 | 0 | 101·6 | 0·3 | 101·6 | 0·6 | 101·7 | 0·9 | 101·8 | 1·2 | 101·9 | 1·5 | 102·1 | 1·8 |
| 11 | 101·9 | 0 | 101·9 | 0·3 | 101·9 | 0·7 | 102·0 | 1·0 | 102·1 | 1·4 | 102·3 | 1·7 | 102·4 | 2·0 |
| 12 | 102·2 | 0 | 102·2 | 0·4 | 102·3 | 0·7 | 102·4 | 1·1 | 102·5 | 1·5 | 102·6 | 1·9 | 102·8 | 2·2 |
| 13 | 102·6 | 0 | 102·6 | 0·4 | 102·7 | 0·8 | 102·8 | 1·2 | 102·9 | 1·6 | 103 3 | 2·0 | 103·2 | 2·4 |
| 14 | 103·1 | 0 | 103·1 | 0·4 | 103·1 | 0·9 | 103·2 | 1·3 | 103·3 | 1·7 | 103 5 | 2·2 | 103·6 | 2·6 |
| 15 | 103·5 | 0 | 103·5 | 0·5 | 103 6 | 0·9 | 103·7 | 1·4 | 103·8 | 1·9 | 103 9 | 2·3 | 104·1 | 2·8 |
| 16 | 104·0 | 0 | 104·0 | 0·5 | 104·1 | 1·0 | 104·2 | 1·5 | 104·3 | 2·0 | 104·4 | 2·5 | 104·6 | 3·0 |
| 17 | 104·6 | 0 | 104 6 | 0·5 | 104 6 | 1·1 | 104·7 | 1·6 | 104·8 | 2·1 | 104·7 | 2·7 | 105·1 | 3·2 |
| 18 | 105·1 | 0 | 105·2 | 0·6 | 105 2 | 1·1 | 105 3 | 1·7 | 105·4 | 2·3 | 105·5 | 2·8 | 105·7 | 3·4 |
| 19 | 105·8 | 0 | 105·8 | 0·6 | 105 8 | 1·2 | 105 9 | 1·8 | 106·0 | 2·4 | 106·2 | 3·0 | 106·3 | 3·6 |
| 20 | 106·4 | 0 | 106·4 | 0·6 | 106·5 | 1·3 | 106 6 | 1·9 | 106·7 | 2·5 | 106 8 | 3·2 | 107·0 | 3·8 |
| 21 | 107·1 | 0 | 107·1 | 0·7 | 107·2 | 1·3 | 107·3 | 2·0 | 107·4 | 2·7 | 107·5 | 3·4 | 107·7 | 4·0 |
| 22 | 107·8 | 0 | 107·9 | 0·7 | 107·9 | 1·4 | 108·0 | 2·1 | 108·1 | 2·8 | 108·3 | 3·5 | 108·4 | 4·2 |
| 23 | 108·6 | 0 | 108·6 | 0·7 | 108·7 | 1·5 | 108·8 | 2·2 | 108·9 | 3·0 | 109·0 | 3·7 | 109·2 | 4·5 |
| 24 | 109·5 | 0 | 109·5 | 0·8 | 109·5 | 1·5 | 109 6 | 2·3 | 109·7 | 3·1 | 109·9 | 3·9 | 110·1 | 4·7 |
| 25 | 110·3 | 0 | 110·4 | 0·8 | 110·1 | 1·6 | 110·5 | 2·4 | 110·6 | 3·3 | 110·8 | 4·1 | 110·9 | 4·9 |
| 26 | 111·3 | 0 | 111·3 | 0·8 | 111·3 | 1·7 | 111·4 | 2·6 | 111·5 | 3·4 | 111·7 | 4·3 | 111·9 | 5·1 |
| 27 | 112·2 | 0 | 112·2 | 0·9 | 112·3 | 1·8 | 112·4 | 2·7 | 112·5 | 3·5 | 112·7 | 4·5 | 112·8 | 5·3 |
| 28 | 113·3 | 0 | 113·3 | 0·9 | 113·3 | 1·9 | 113·4 | 2·8 | 113·5 | 3·7 | 113·7 | 4·7 | 113·9 | 5·6 |
| 29 | 114·3 | 0 | 114·4 | 1·0 | 114·4 | 1·9 | 114·5 | 2·9 | 114·6 | 3·9 | 114·8 | 4·8 | 115·0 | 5·8 |
| 30 | 115 5 | 0 | 115·5 | 1·0 | 115·4 | 2·0 | 115·6 | 3·0 | 115·7 | 4·0 | 115·9 | 5·0 | 116·1 | 6·1 |
| 31 | 116·7 | 0 | 116·7 | 1·0 | 116·7 | 2·1 | 116·8 | 3·1 | 116·9 | 4·2 | 117·1 | 5·3 | 117·3 | 6 3 |
| 32 | 117·9 | 0 | 117·9 | 1·1 | 118·0 | 2·2 | 118·1 | 3·3 | 118·2 | 4·4 | 118·4 | 5·5 | 118·6 | 6·6 |
| 33 | 119·2 | 0 | 119·3 | 1·1 | 119·3 | 2·3 | 119·4 | 3·4 | 119·5 | 4·5 | 119·7 | 5·7 | 119·9 | 6·8 |
| 34 | 120·6 | 0 | 120·6 | 1·2 | 120·7 | 2·4 | 120·8 | 3·5 | 120·9 | 4·7 | 121·1 | 5·9 | 121·3 | 7·1 |
| 35 | 122·1 | 0 | 122·1 | 1·2 | 122·1 | 2·4 | 122·2 | 3·7 | 122·4 | 4·9 | 122·5 | 6·2 | 122·7 | 7·4 |
| 36 | 123·6 | 0 | 123·6 | 1·3 | 123·7 | 2·5 | 123·8 | 3·8 | 123·9 | 5·1 | 124·1 | 6·4 | 124·3 | 7·6 |
| 37 | 125·2 | 0 | 125·2 | 1·3 | 125·3 | 2·6 | 125·4 | 3·9 | 125·5 | 5·3 | 125·7 | 6·6 | 125·9 | 7·9 |
| 38 | 126·9 | 0 | 126 9 | 1·4 | 127·0 | 2·7 | 127·1 | 4·1 | 127·2 | 5·5 | 127·4 | 6·8 | 127·6 | 8·2 |
| 39 | 128·7 | 0 | 128·7 | 1·4 | 128·8 | 2·8 | 128·9 | 4·2 | 129·0 | 5·7 | 129·2 | 7·1 | 129·4 | 8·5 |
| 40 | 130·5 | 0 | 130·6 | 1·5 | 130·6 | 2·9 | 130·7 | 4·4 | 130·9 | 5·9 | 131·0 | 7·3 | 131·3 | 8·8 |
| 41 | 132·5 | 0 | 132·5 | 1·5 | 132·6 | 3·0 | 132·7 | 4·6 | 132·8 | 6·1 | 133·0 | 7·6 | 133·2 | 9·1 |
| 42 | 134·6 | 0 | 134·6 | 1·6 | 134·6 | 3·1 | 134·7 | 4·7 | 134·9 | 6·3 | 135·1 | 7·9 | 135·3 | 9·5 |
| 43 | 136·7 | 0 | 136·8 | 1·6 | 136·8 | 3·3 | 136·9 | 4·9 | 137·1 | 6·5 | 137·3 | 8·2 | 137·5 | 9·8 |
| 44 | 139·0 | 0 | 139·0 | 1·7 | 139·1 | 3·4 | 139·2 | 5·1 | 139·4 | 6·7 | 139·5 | 8·4 | 139·8 | 10·1 |
| 45 | 141·4 | 0 | 141·4 | 1·7 | 141·5 | 3·5 | 141·6 | 5·2 | 141·8 | 7·0 | 142·0 | 8·7 | 142·2 | 10·5 |
| 46 | 144·0 | 0 | 144·0 | 1·8 | 144·0 | 3·6 | 144·2 | 5·4 | 144·3 | 7·2 | 144·5 | 9·1 | 144·7 | 10·9 |
| 47 | 146·6 | 0 | 146·6 | 1·9 | 146·7 | 3·7 | 146·8 | 5·6 | 147·0 | 7·5 | 147·2 | 9·4 | 147·4 | 11·3 |
| 48 | 149·4 | 0 | 149·5 | 1·9 | 149·5 | 3·9 | 149·7 | 5·8 | 149·8 | 7·8 | 150·0 | 9·7 | 150·3 | 11·7 |
| 49 | 152·4 | 0 | 152·4 | 2·0 | 152·5 | 4·0 | 152·6 | 6·0 | 152·1 | 8·0 | 153·0 | 10·1 | 153·3 | 12·1 |
| 50 | 155·6 | 0 | 155·6 | 2·1 | 155·7 | 4·2 | 155·8 | 6·2 | 155·7 | 8·3 | 156·2 | 10·4 | 156·4 | 12·5 |
| 51 | 158·9 | 0 | 158·9 | 2·2 | 159·0 | 4·3 | 159·1 | 6·5 | 159·3 | 8·6 | 159·5 | 10·8 | 159·8 | 13·0 |
| 52 | 162·4 | 0 | 162·5 | 2·2 | 162·5 | 4·5 | 162·6 | 6·7 | 162·8 | 8·9 | 163·0 | 11·2 | 163·3 | 13·4 |
| 53 | 166·2 | 0 | 166·2 | 2·3 | 166·3 | 4·6 | 166·4 | 6·9 | 166·6 | 9·3 | 166·8 | 11·6 | 167·1 | 13·9 |
| 54 | 170·1 | 0 | 170·2 | 2·4 | 170·2 | 4·8 | 170·4 | 7·2 | 170·5 | 9·6 | 170·8 | 12·0 | 171·1 | 14·5 |
| 55 | 174·3 | 0 | 174·4 | 2·5 | 174·4 | 5·0 | 174·6 | 7·5 | 174·8 | 10·0 | 175·0 | 12·5 | 175·3 | 15·0 |
| 56 | 178·8 | 0 | 178·9 | 2·6 | 178·9 | 5·2 | 179·5 | 7·8 | 179·3 | 10·4 | 179·5 | 13·0 | 179·8 | 15·6 |
| 57 | 183·6 | 0 | 183·6 | 2·7 | 183·7 | 5·4 | 183·9 | 8·1 | 184·1 | 10·8 | 184·3 | 13·5 | 184·6 | 16·2 |
| 58 | 188·7 | 0 | 188·7 | 2·8 | 188·2 | 5·6 | 189·0 | 8·4 | 189·2 | 11·2 | 189·4 | 14·0 | 189·7 | 16·8 |
| 59 | 194·2 | 0 | 194·2 | 2·9 | 194·3 | 5·8 | 194·4 | 8·7 | 194·6 | 11·6 | 194·9 | 14·6 | 195·2 | 17·5 |
| 60 | 200·0 | 0 | 200·0 | 3·0 | 200·1 | 6·0 | 200·3 | 9·1 | 200·5 | 12·1 | 200·8 | 15·1 | 201·1 | 18·2 |

## SPHERICAL TRAVERSE TABLE

| | 0° | | 1° | | 2° | | 3° | | 4° | | 5° | | 6° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 61 | 206·3 | 0 | 206·3 | 3·1 | 206·4 | 6·3 | 206 5 | 9·4 | 206·8 | 12·6 | 207·1 | 15 8 | 207·4 | 19·0 |
| 62 | 213·0 | 0 | 213·0 | 3·3 | 213·2 | 6·6 | 213·3 | 9 9 | 213 5 | 13 1 | 213 8 | 16·4 | 214·2 | 19·8 |
| 63 | 220·3 | 0 | 220·3 | 3·4 | 220·4 | 6·8 | 220 6 | 10·3 | 220·8 | 13·7 | 221·1 | 17·2 | 221·5 | 20 6 |
| 64 | 228·1 | 0 | 228·2 | 3·6 | 228·3 | 7·2 | 228 4 | 10 7 | 228·7 | 14·3 | 229 0 | 17·9 | 229·4 | 21·5 |
| 65 | 236 6 | 0 | 236·7 | 3·7 | 236 8 | 7·5 | 236 9 | 11·2 | 237·2 | 15·0 | 237·5 | 18·8 | 237·9 | 22·5 |
| 66 | 245·8 | 0 | 245·9 | 3·9 | 246 0 | 7·8 | 246 2 | 11·8 | 246·5 | 15·7 | 246 8 | 19·6 | 247·2 | 23·6 |
| 67 | 255·9 | 0 | 256·0 | 4·1 | 256·1 | 8·2 | 256 2 | 12·3 | 256·6 | 16 5 | 256 9 | 20 6 | 257·3 | 24·8 |
| 68 | 266 9 | 0 | 267·0 | 4·3 | 267·1 | 8·6 | 267·3 | 13·0 | 267·6 | 17·3 | 268 0 | 21·7 | 268·4 | 26·0 |
| 69 | 279·0 | 0 | 279·1 | 4·5 | 279·2 | 9·1 | 279·4 | 13 6 | 279·7 | 18·2 | 280·1 | 22·8 | 280·6 | 27·4 |
| 70 | 292·4 | 0 | 292·4 | 4 8 | 292·6 | 9·6 | 292·8 | 14·4 | 293·1 | 19·2 | 293 5 | 24 0 | 294·0 | 28·9 |
| 71 | 307·2 | 0 | 307·2 | 5·1 | 307·3 | 10·1 | 307 6 | 15·2 | 307·9 | 20·3 | 308·3 | 25 4 | 308·9 | 30·5 |
| 72 | 323·6 | 0 | 323·7 | 5·4 | 323·8 | 10·7 | 324·1 | 16·1 | 324 4 | 21·5 | 324 8 | 26 9 | 325·4 | 32·3 |
| 73 | 342·0 | 0 | 342·1 | 5·7 | 342·2 | 11·4 | 342·4 | 17·1 | 342 9 | 22·9 | 343 3 | 28·6 | 343 9 | 34·4 |
| 74 | 362·8 | 0 | 362·9 | 6·1 | 363·0 | 12·2 | 363·3 | 18·3 | 363 7 | 24·4 | 364 2 | 30 5 | 364·8 | 36·6 |
| 75 | 386·4 | 0 | 386·4 | 6·5 | 386·6 | 13·0 | 386·9 | 19 6 | 387·3 | 26·1 | 387·8 | 32·6 | 388·5 | 39·2 |
| 76 | 413·3 | 0 | 404·0 | 7·0 | 413·6 | 14·0 | 413 9 | 21·0 | 414 4 | 28·0 | 414 9 | 35·1 | 415 6 | 42·2 |
| 77 | 444·5 | 0 | 444 6 | 7·6 | 444·8 | 15·1 | 445·2 | 22·7 | 445·6 | 30 3 | 446 1 | 37 9 | 447·0 | 43·5 |
| 78 | 481·0 | 0 | 481·0 | 8·2 | 481·3 | 16·4 | 481·6 | 24 6 | 482·1 | 32·9 | 482·8 | 41·2 | 483 6 | 49·4 |
| 79 | 524·1 | 0 | 524·2 | 9·0 | 524·4 | 18·0 | 524 8 | 27·0 | 525·4 | 36·0 | 526 1 | 45 0 | 527·0 | 54·1 |
| 80 | 575·9 | 0 | 576·0 | 9·9 | 576·2 | 19·8 | 576·7 | 29·7 | 577·3 | 39·7 | 578·2 | 49 6 | 579·1 | 59·6 |

| | 7° | | 8° | | 9° | | 10° | | 11° | | 12° | | 13° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 7 | 101·5 | 1·5 | | | | | | | | | | | | |
| 8 | 101·7 | 1·7 | 102·0 | 2·0 | | | | | | | | | | |
| 9 | 102·0 | 1·9 | 102·2 | 2·2 | 102·5 | 2·5 | | | | | | | | |
| 10 | 102·3 | 2·2 | 102·5 | 2·5 | 102·8 | 2·8 | 103·1 | 3·1 | | | | | | |
| 11 | 102·6 | 2·4 | 102·9 | 2·7 | 103·1 | 3·1 | 103·4 | 3·4 | 103·8 | 3 8 | | | | |
| 12 | 103·0 | 2·6 | 103·2 | 3·0 | 103·5 | 3·4 | 103·8 | 3·7 | 104·1 | 4·1 | 104·5 | 4 5 | | |
| 13 | 103·4 | 2·8 | 103·6 | 3·2 | 103·9 | 3·7 | 104·2 | 4·1 | 104·5 | 4 5 | 104·9 | 4 9 | 105·3 | 5·3 |
| 14 | 103·8 | 3·1 | 104·1 | 3·5 | 104·3 | 3·9 | 104·6 | 4·4 | 105·0 | 4·8 | 105 4 | 5 3 | 105 8 | 5·8 |
| 15 | 104·3 | 3·3 | 104·5 | 3·8 | 104·8 | 4·2 | 105·1 | 4·7 | 105·5 | 5·2 | 105·8 | 5·7 | 106 2 | 6·2 |
| 16 | 104·8 | 3·5 | 105·0 | 4·0 | 105·3 | 4·5 | 105·6 | 5·1 | 106·0 | 5·6 | 106 4 | 6 1 | 106 8 | 6 6 |
| 17 | 105·3 | 3·7 | 105·6 | 4·3 | 105·9 | 4·8 | 106·2 | 5·4 | 106·5 | 5·9 | 106 9 | 6·5 | 107·3 | 7·1 |
| 18 | 106·0 | 4·0 | 106·2 | 4·6 | 106·5 | 5·1 | 106·8 | 5·7 | 107·1 | 6·3 | 107·5 | 6·9 | 107 9 | 7·5 |
| 19 | 106·6 | 4·2 | 106·8 | 4·8 | 107·1 | 5·5 | 107·4 | 6·1 | 107·7 | 6·7 | 108 1 | 7·3 | 108 5 | 7·9 |
| 20 | 107·2 | 4·5 | 107·5 | 5·1 | 107·7 | 5·8 | 108·1 | 6·4 | 108·4 | 7·1 | 108 8 | 7·7 | 109·2 | 8·4 |
| 21 | 107·9 | 4·7 | 108·2 | 5·4 | 108·4 | 6·1 | 108·8 | 6·8 | 109·1 | 7·5 | 109 5 | 8·2 | 109 9 | 8 9 |
| 22 | 108·7 | 5·0 | 108·9 | 5·7 | 109·2 | 6·4 | 109·5 | 7·1 | 109·9 | 7·8 | 110·3 | 8·6 | 110·7 | 9·3 |
| 23 | 109·4 | 5·2 | 109·7 | 6·0 | 110·0 | 6·7 | 110·3 | 7·5 | 110·7 | 8·3 | 111·1 | 9·0 | 111·5 | 9 8 |
| 24 | 110·3 | 5·5 | 110·5 | 6·3 | 110·8 | 7·0 | 111·0 | 7·9 | 111·5 | 8·7 | 111·9 | 9·5 | 112·3 | 10·3 |
| 25 | 111·2 | 5·7 | 111·4 | 6 6 | 111·7 | 7·4 | 111·9 | 8·2 | 112·4 | 9·1 | 112·8 | 9·9 | 113·2 | 10 8 |
| 26 | 112·1 | 6·0 | 112·4 | 6 8 | 112·6 | 7·7 | 112·9 | 8·6 | 113·4 | 9·5 | 113 7 | 10·4 | 114·2 | 11·3 |
| 27 | 113·1 | 6·3 | 113·3 | 7·2 | 113·6 | 8·1 | 114·0 | 9·0 | 114·3 | 9·9 | 114·7 | 10 8 | 115·2 | 11·8 |
| 28 | 114·1 | 6·5 | 114·4 | 7·5 | 114·7 | 8·4 | 115·1 | 9·4 | 115·4 | 10·3 | 115·8 | 11·3 | 116·2 | 12·3 |
| 29 | 115·2 | 6·8 | 115·5 | 7·8 | 115·8 | 8·8 | 116·1 | 9·8 | 116·5 | 10·8 | 116 9 | 11·8 | 117·3 | 12·8 |
| 30 | 116·3 | 7·1 | 116·6 | 8·1 | 116·9 | 9·1 | 117·2 | 10·2 | 117·6 | 11·2 | 118·0 | 12·3 | 118·5 | 13·3 |
| 31 | 117·5 | 7·4 | 117·8 | 8·4 | 118·1 | 9·5 | 118·5 | 10·6 | 118·8 | 11·7 | 119·3 | 12·8 | 119·7 | 13·9 |
| 32 | 118·6 | 7·7 | 119·1 | 8·8 | 119·4 | 9·9 | 119·8 | 11·0 | 120·1 | 12·1 | 120·6 | 13·3 | 121·0 | 14·4 |
| 33 | 120·1 | 8·0 | 120·4 | 9·1 | 120·7 | 10·3 | 121·1 | 11·4 | 121·5 | 12·6 | 121·9 | 13·8 | 122·7 | 15·0 |
| 34 | 121·5 | 8·3 | 121·8 | 9·5 | 122·1 | 10·7 | 122·5 | 11·9 | 122·9 | 13·1 | 123·3 | 14·3 | 123·8 | 15 6 |
| 35 | 123·0 | 8·6 | 123·3 | 9·8 | 123·6 | 11·1 | 124·0 | 12·3 | 124·4 | 13·6 | 124·8 | 14·9 | 125·3 | 16·2 |
| 36 | 124·5 | 8·9 | 124·8 | 10·2 | 125·1 | 11·5 | 125·5 | 12·8 | 125·9 | 14·1 | 126·4 | 15·4 | 126·9 | 16·7 |
| 37 | 126·2 | 9·3 | 126·4 | 10·6 | 126·8 | 11·9 | 127·1 | 13·3 | 127·6 | 14·6 | 128·0 | 16·0 | 128·5 | 17·4 |
| 38 | 127·9 | 9·6 | 128·1 | 11·0 | 128·5 | 12·4 | 128·9 | 13·8 | 129·3 | 15·2 | 129·7 | 16·6 | 130·2 | 18·0 |
| 39 | 129·6 | 9·9 | 129·9 | 11·4 | 130·3 | 12·8 | 130·7 | 14·3 | 131·1 | 15·7 | 131·5 | 17·2 | 132·1 | 18·7 |
| 40 | 131·5 | 10·3 | 131·8 | 11·8 | 132·2 | 13·3 | 132·6 | 14·8 | 133·0 | 16·3 | 133·5 | 17·8 | 134·0 | 19·4 |
| 41 | 133·5 | 10·7 | 133·8 | 12·2 | 134·1 | 13·8 | 134·5 | 15·3 | 135·0 | 16·9 | 135·5 | 18·5 | 136 0 | 20 1 |
| 42 | 135·6 | 11·1 | 135·9 | 12·6 | 136·2 | 14·3 | 136 6 | 15·9 | 137·1 | 17·5 | 137·6 | 19·1 | 138·1 | 20 8 |
| 43 | 137·8 | 11·4 | 138·1 | 13·1 | 138·4 | 14·8 | 138·8 | 16·4 | 139·3 | 18·1 | 139 8 | 19 8 | 140 3 | 21 5 |

## SPHERICAL TRAVERSE TABLE.

| | 7° | | 8° | | 9° | | 10° | | 11° | | 12° | | 13° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 44 | 140·1 | 11·9 | 140·4 | 13 6 | 140·7 | 15 4 | 141·2 | 17·0 | 141·6 | 18·8 | 142·1 | 20·5 | 142·7 | 22·3 |
| 45 | 142·5 | 12·3 | 142·8 | 14 0 | 143·2 | 15 8 | 143 6 | 17·6 | 144·1 | 19·4 | 144·6 | 21·3 | 145·1 | 23·1 |
| 46 | 145 0 | 12·7 | 145·4 | 14·5 | 145·7 | 16·4 | 146 2 | 18 3 | 146 6 | 20·1 | 147·2 | 22·0 | 147·7 | 23 9 |
| 47 | 147·7 | 13·2 | 148·1 | 15·1 | 148·5 | 17·0 | 148 9 | 18 9 | 149·4 | 20·8 | 149·9 | 22·8 | 150·8 | 24·8 |
| 48 | 150·6 | 13·6 | 150·9 | 15·6 | 151·3 | 17·6 | 151·7 | 19 6 | 152·2 | 21·6 | 152·8 | 23·6 | 153·4 | 25·6 |
| 49 | 153 6 | 14·1 | 153 9 | 16 2 | 154 3 | 18·2 | 154 8 | 20 3 | 155·3 | 22·4 | 155·9 | 24·4 | 156·4 | 26·6 |
| 50 | 156·7 | 14·6 | 157·1 | 16·7 | 157·5 | 18 9 | 158·0 | 21·0 | 158·5 | 23 2 | 159·0 | 25·3 | 159·7 | 27·5 |
| 51 | 160·1 | 15·2 | 160·5 | 17·4 | 160 9 | 19 6 | 161·4 | 21 8 | 161·9 | 24 0 | 162·5 | 26·2 | 163·1 | 28·5 |
| 52 | 163 6 | 15·7 | 164 0 | 18·0 | 164·4 | 20 3 | 165·0 | 22 6 | 165·5 | 24 9 | 166·1 | 27·2 | 166·7 | 29·5 |
| 53 | 167·4 | 16·3 | 167 8 | 18 6 | 168·2 | 21·0 | 168 7 | 23 4 | 169 3 | 25 8 | 169·9 | 28·2 | 170·5 | 30 6 |
| 54 | 171·4 | 16·9 | 171·8 | 19 3 | 172·2 | 21·8 | 172·8 | 24·3 | 173 3 | 26 8 | 173·9 | 29·3 | 174·6 | 31·8 |
| 55 | 175·7 | 17·5 | 176·1 | 20·1 | 176·5 | 22 6 | 177·0 | 25 2 | 177·6 | 27·8 | 178·2 | 30·4 | 178·9 | 33·0 |
| 56 | 180·2 | 18·2 | 180 6 | 20·8 | 181·1 | 23 5 | 181 6 | 26·1 | 182·2 | 28·8 | 182·8 | 31·5 | 183·5 | 34·2 |
| 57 | 185·0 | 18·9 | 185 4 | 21·6 | 185 9 | 24·4 | 186 4 | 27·1 | 187·0 | 29·9 | 187 7 | 32·7 | 188·4 | 35·5 |
| 58 | 190·1 | 19·6 | 190·6 | 22·5 | 191·1 | 25·3 | 191·6 | 28·2 | 189·2 | 31·1 | 192·9 | 34·0 | 193·6 | 36·9 |
| 59 | 195 6 | 20·4 | 196·1 | 23·4 | 196·6 | 26 4 | 197·2 | 29 3 | 197·8 | 32·3 | 198·5 | 35·4 | 199·3 | 38·4 |
| 60 | 201·5 | 21·3 | 202·0 | 24·3 | 202·5 | 27·4 | 203·1 | 30·5 | 203 7 | 33·7 | 204·5 | 36·8 | 205·3 | 40·0 |
| 61 | 207·8 | 22·1 | 208·3 | 25·3 | 208·8 | 28 6 | 209 9 | 31·8 | 210·1 | 35·1 | 210·9 | 38·3 | 211·7 | 41·6 |
| 62 | 214 6 | 23·1 | 215·1 | 26·4 | 215·7 | 29·8 | 216 3 | 33·2 | 217·0 | 36 6 | 217·8 | 40·0 | 218·6 | 43·4 |
| 63 | 221·9 | 24·1 | 222·4 | 27·6 | 223·0 | 31·1 | 223·7 | 34·6 | 224·4 | 38·1 | 225·2 | 41·7 | 226·1 | 45·3 |
| 64 | 229·8 | 25·2 | 230·4 | 28·8 | 231·0 | 32·5 | 231·6 | 36·1 | 232·4 | 39 8 | 233·2 | 43·6 | 234·1 | 47·3 |
| 65 | 238·4 | 26·3 | 238·9 | 30·1 | 239 6 | 34·0 | 240·3 | 37·8 | 241·0 | 41·7 | 241·9 | 45·6 | 242·8 | 49·5 |
| 66 | 247·7 | 27·6 | 248·4 | 31·6 | 248·9 | 35 6 | 249·7 | 39·6 | 250·5 | 43·7 | 251·4 | 47·7 | 252·3 | 51·8 |
| 67 | 257·9 | 28·9 | 258·4 | 33·1 | 259·1 | 37·3 | 259·9 | 41·5 | 260·7 | 45·8 | 261·6 | 50·1 | 262·7 | 54·4 |
| 68 | 269·0 | 30·4 | 269·6 | 34·8 | 270·3 | 39·2 | 271·1 | 43 6 | 271·9 | 48·1 | 272·9 | 52·6 | 274·0 | 57·1 |
| 69 | 281·1 | 32·0 | 281·8 | 36·6 | 282·5 | 41·3 | 283·4 | 45·9 | 284·3 | 50·6 | 285·3 | 55·4 | 286·4 | 60·1 |
| 70 | 294·6 | 33·7 | 295·3 | 38·6 | 296 0 | 43·5 | 296·9 | 48·4 | 297·9 | 53·4 | 298·9 | 58·4 | 300·1 | 63·4 |
| 71 | 309·5 | 35·7 | 310·2 | 40·8 | 311·0 | 46 0 | 311·9 | 51·2 | 312·9 | 56·4 | 314·0 | 61·7 | 315·2 | 67·0 |
| 72 | 326·0 | 37·8 | 326 8 | 43·2 | 327·6 | 48·7 | 328·6 | 54·3 | 329 6 | 59·8 | 330·8 | 65·4 | 332·1 | 71·0 |
| 73 | 344 6 | 40·2 | 345·4 | 46·0 | 346·3 | 51·8 | 347·3 | 57·7 | 348·4 | 63·6 | 349·7 | 69·5 | 351·0 | 75·5 |
| 74 | 365·5 | 42·8 | 366·4 | 49·0 | 367·3 | 55·2 | 368·4 | 61·7 | 369·6 | 67·8 | 370·9 | 74·1 | 372·3 | 80·5 |
| 75 | 389·0 | 45·8 | 390·2 | 52·5 | 391·2 | 59·1 | 392·3 | 65·8 | 393·6 | 72·5 | 395·1 | 79·3 | 396·5 | 86·2 |
| 76 | 416·5 | 49·2 | 417·4 | 56·4 | 418·5 | 63·5 | 419·7 | 70·7 | 421·1 | 78·0 | 422·6 | 85·2 | 424·3 | 92·6 |
| 77 | 447·9 | 53·2 | 448·9 | 60·9 | 450·1 | 68·6 | 451·4 | 76·4 | 452·9 | 84·2 | 454·5 | 92·1 | 456·2 | 100·0 |
| 78 | 484·6 | 57·8 | 485·7 | 66·1 | 487·0 | 74·5 | 488·4 | 83·0 | 490·0 | 91·4 | 491·7 | 100·0 | 493·6 | 108·6 |
| 79 | 528·0 | 63·1 | 529·2 | 72·3 | 530·6 | 81·5 | 532·2 | 90·7 | 533·9 | 100·0 | 535·8 | 109·3 | 537·9 | 118·8 |
| 80 | 580·2 | 69·6 | 581·5 | 79·7 | 583·1 | 89·8 | 584·8 | 100·0 | 586·7 | 110·2 | 588·7 | 120·9 | 591·0 | 130·9 |

| | 14° | | 15° | | 16° | | 17° | | 18° | | 19° | | 20° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 14 | 106·2 | 6·2 | | | | | | | | | | | | |
| 15 | 106·7 | 6·7 | 107·2 | 7·2 | | | | | | | | | | |
| 16 | 107·2 | 7·1 | 107·7 | 7·7 | 108·2 | 8·2 | | | | | | | | |
| 17 | 107·8 | 7·6 | 108·3 | 8·2 | 108·8 | 8·8 | 109·3 | 9·3 | | | | | | |
| 18 | 108·4 | 8·1 | 108·9 | 8·7 | 109·3 | 9·3 | 109·9 | 9·9 | 110·6 | 10·6 | | | | |
| 19 | 109·0 | 8·6 | 109·5 | 9·2 | 110·0 | 9·9 | 110·6 | 10·5 | 111·2 | 11·2 | 111·9 | 11·9 | | |
| 20 | 109·7 | 9·1 | 110·2 | 9 8 | 110·7 | 10·4 | 111·3 | 11·1 | 111·9 | 11·8 | 112·5 | 12·5 | 113·2 | 13·2 |
| 21 | 110·4 | 9·6 | 110·9 | 10·3 | 111·4 | 10·0 | 112·0 | 11·7 | 112·6 | 12·5 | 113·3 | 13·2 | 114·0 | 14·0 |
| 22 | 111·2 | 10·1 | 111·7 | 10·8 | 112·2 | 11·6 | 112·8 | 12·3 | 113·4 | 13·1 | 114·1 | 13·9 | 114·8 | 14·7 |
| 23 | 112·0 | 10·6 | 112·5 | 11·4 | 113·0 | 12·2 | 113·6 | 13·0 | 114·2 | 13·8 | 114·9 | 14·6 | 115·6 | 15·4 |
| 24 | 112·8 | 11·1 | 113·3 | 11·9 | 113·9 | 12·8 | 114·5 | 13·6 | 115·1 | 14·5 | 115·8 | 15·3 | 116·5 | 16·2 |
| 25 | 113·7 | 11·6 | 114·2 | 12·5 | 114·8 | 13·4 | 115·4 | 14·3 | 116·0 | 15·1 | 116·7 | 16·1 | 117·4 | 17·0 |
| 26 | 114·6 | 12·2 | 115·2 | 13·1 | 115·7 | 14·0 | 116·3 | 14·9 | 117·0 | 15·8 | 117·7 | 17·0 | 118·4 | 17·7 |
| 27 | 115·7 | 12·7 | 116·2 | 13·6 | 116·8 | 14·6 | 117·4 | 15·6 | 118·0 | 16·6 | 118·8 | 17·5 | 119·4 | 18·5 |
| 28 | 116·7 | 13·3 | 117·3 | 14·2 | 117·8 | 15·2 | 118·4 | 16·3 | 119·1 | 17·3 | 119·8 | 18·3 | 120·5 | 19·3 |
| 29 | 117·8 | 13·8 | 118·4 | 14·8 | 118·9 | 15·9 | 119·6 | 16·9 | 120·2 | 18·0 | 120·9 | 19·1 | 121·7 | 20·2 |
| 30 | 119·0 | 14·4 | 119·5 | 15·5 | 120·1 | 16 6 | 120·7 | 17·6 | 121·4 | 18·8 | 122·1 | 19·9 | 122·9 | 21·0 |
| 31 | 120·2 | 15 0 | 120·8 | 16·1 | 121·4 | 17·2 | 122·0 | 18·4 | 122·7 | 19·5 | 123·4 | 20·7 | 124·1 | 21·9 |
| 32 | 121·5 | 15·6 | 122·1 | 16·7 | 122·7 | 17·9 | 123·3 | 19·1 | 124·0 | 20·3 | 124·7 | 21·5 | 125·5 | 22·7 |

## SPHERICAL TRAVERSE TABLE.

| | 14° | | 15° | | 16° | | 17° | | 18° | | 19° | | 20° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 33 | 122·9 | 16·2 | 123·4 | 17·4 | 124·0 | 18·6 | 124·7 | 19·9 | 125·4 | 21·1 | 126·1 | 22·4 | 126 9 | 23·6 |
| 34 | 124·3 | 16·8 | 124·9 | 18·1 | 125·5 | 19·3 | 126·1 | 20·6 | 126·8 | 21·9 | 127·6 | 23·2 | 128·4 | 24 6 |
| 35 | 125·8 | 17·5 | 126·4 | 18·8 | 127·0 | 20·1 | 127·7 | 21·4 | 128·4 | 22·7 | 129·1 | 24·1 | 129·9 | 25·5 |
| 36 | 127·4 | 18·1 | 128·0 | 19·5 | 128·6 | 20·8 | 129·2 | 22·2 | 130·0 | 23·6 | 130·7 | 25·0 | 131·5 | 26·4 |
| 37 | 129·0 | 18·8 | 129·6 | 20·2 | 130·3 | 21·6 | 130·9 | 23·0 | 131·7 | 24·5 | 132·4 | 25·9 | 133·2 | 27·4 |
| 38 | 130·8 | 19·5 | 131·4 | 20·9 | 132·0 | 22·4 | 132·7 | 23·9 | 133·4 | 25·4 | 134·2 | 26·9 | 135·0 | 28·4 |
| 39 | 132·6 | 20·2 | 133·2 | 21·7 | 133·9 | 23·2 | 134·6 | 24·8 | 135·3 | 26·3 | 136·1 | 27·9 | 136 9 | 29·5 |
| 40 | 134·5 | 20·9 | 135·1 | 22·5 | 135·8 | 24·1 | 136·5 | 25·6 | 137·3 | 27·3 | 138·1 | 28·9 | 138 9 | 30·5 |
| 41 | 136·5 | 21·7 | 137·2 | 23·3 | 137·8 | 24·9 | 138·6 | 26·6 | 139·3 | 28·2 | 140·1 | 29·9 | 141·0 | 31·6 |
| 42 | 138·7 | 22·4 | 139·3 | 24·1 | 140·0 | 25·8 | 140·7 | 27·5 | 141·5 | 29·3 | 142·3 | 31·0 | 143·2 | 32·8 |
| 43 | 140·9 | 23·2 | 141·6 | 25·0 | 142·2 | 26·7 | 143·0 | 28·5 | 143·8 | 30·3 | 144·6 | 32·1 | 145·5 | 33·9 |
| 44 | 143·3 | 24·1 | 143·9 | 25·9 | 144·6 | 27·7 | 145·4 | 29·5 | 146·2 | 31·4 | 147·0 | 33·2 | 147·9 | 35·1 |
| 45 | 145·7 | 24·9 | 146·4 | 26·8 | 147·1 | 28·7 | 147·9 | 30·6 | 148·7 | 32·5 | 149·6 | 34·4 | 150·5 | 36·4 |
| 46 | 148·4 | 25·8 | 149·0 | 27·7 | 149·8 | 29·7 | 150·5 | 31·7 | 151·4 | 33·6 | 152·2 | 35·7 | 153·2 | 37·7 |
| 47 | 151·1 | 26·7 | 151·8 | 28·7 | 152·5 | 30·7 | 153·3 | 32·8 | 154·2 | 34·8 | 155·1 | 36·9 | 156·0 | 39·0 |
| 48 | 154·0 | 27·7 | 154·7 | 29·8 | 155·5 | 31·8 | 156·3 | 34·0 | 157·1 | 36·1 | 158·1 | 38·2 | 159·0 | 40·4 |
| 49 | 157·1 | 28·7 | 157·8 | 30·8 | 158·6 | 33·0 | 159·4 | 35·2 | 160·3 | 37·4 | 161·2 | 39·6 | 162·2 | 41·9 |
| 50 | 160·3 | 29·7 | 161·1 | 31·9 | 161·8 | 34·2 | 162·7 | 36·4 | 163·6 | 38·7 | 164·5 | 41·1 | 165·6 | 43·4 |
| 51 | 163·8 | 30·8 | 164·5 | 33·1 | 165·3 | 35·4 | 166·2 | 37·8 | 167·1 | 40·1 | 168·1 | 42·5 | 169·1 | 44·9 |
| 52 | 167·4 | 31·9 | 168·2 | 34·3 | 169·0 | 36·7 | 169·8 | 39·1 | 170·8 | 41·6 | 171·8 | 44·1 | 172·8 | 46·6 |
| 53 | 171·2 | 33·1 | 172·0 | 35·6 | 172·9 | 38·0 | 173·8 | 40·6 | 174·7 | 43·1 | 175·7 | 45·7 | 176·8 | 48·3 |
| 54 | 175·3 | 34·3 | 176·1 | 36·9 | 177·0 | 39·5 | 177·9 | 42·1 | 178·9 | 44·7 | 179·9 | 47·4 | 181·0 | 50·1 |
| 55 | 179·7 | 35·6 | 180·5 | 38·3 | 181·4 | 40·9 | 182·3 | 43·7 | 183·3 | 46·4 | 184·4 | 49·2 | 185·5 | 52·0 |
| 56 | 184·3 | 37·0 | 185·1 | 39·7 | 186·0 | 42·5 | 187·0 | 45·3 | 188·0 | 48·2 | 189·1 | 51·0 | 190·3 | 54·0 |
| 57 | 189·2 | 38·4 | 190·1 | 41·3 | 191·0 | 44·2 | 192·0 | 47·1 | 193·1 | 50·0 | 194·2 | 53·0 | 195·4 | 56·0 |
| 58 | 194·5 | 39·9 | 195·3 | 42·9 | 196·3 | 45·9 | 197·3 | 48·9 | 198·4 | 52·0 | 199·6 | 55·1 | 200·8 | 58·2 |
| 59 | 200·1 | 41·5 | 201·0 | 44·6 | 202·0 | 47·7 | 203·0 | 50·9 | 204·2 | 54·1 | 205·3 | 57·3 | 206·6 | 60·6 |
| 60 | 206·1 | 43·2 | 207·1 | 46·4 | 208·1 | 49·7 | 209·1 | 53·0 | 210·3 | 56·3 | 211·5 | 59·6 | 212·8 | 63·0 |
| 61 | 212·6 | 45·0 | 213·5 | 48·3 | 214·6 | 51·7 | 215·7 | 55·2 | 216·9 | 58·6 | 218·2 | 62·1 | 219·5 | 65·7 |
| 62 | 219·5 | 46·9 | 220·5 | 50·4 | 221·6 | 53·9 | 222·7 | 57·5 | 224·0 | 61·1 | 225·3 | 64·8 | 226·7 | 68·4 |
| 63 | 227·0 | 48·9 | 228·0 | 52·6 | 229·1 | 56·3 | 230·3 | 60·0 | 231·6 | 63·8 | 233·0 | 67·6 | 234·4 | 71·4 |
| 64 | 235·1 | 51·1 | 236·2 | 54·9 | 237·3 | 58·8 | 238·5 | 62·7 | 239·9 | 66·6 | 241·3 | 70·6 | 242·8 | 74·6 |
| 65 | 243·9 | 53·5 | 245·0 | 57·5 | 246·2 | 61·5 | 247·4 | 65·6 | 248·8 | 69·7 | 250·3 | 73·8 | 251·8 | 78·1 |
| 66 | 253·4 | 56·0 | 254·5 | 60·2 | 255·8 | 64·4 | 257·1 | 68·7 | 258·5 | 73·0 | 260·0 | 77·3 | 261·6 | 81·7 |
| 67 | 263·8 | 58·7 | 265·0 | 63·2 | 266·2 | 67·5 | 267·6 | 72·0 | 269·1 | 76·5 | 270·7 | 81·1 | 272·4 | 85·7 |
| 68 | 275·1 | 61·7 | 276·4 | 66·3 | 277·7 | 71·0 | 279·1 | 75·7 | 280·7 | 80·4 | 282·3 | 85·2 | 284·1 | 90·1 |
| 69 | 287·6 | 64·9 | 288·9 | 69·8 | 290·3 | 74·7 | 291·8 | 79·6 | 293·4 | 84·6 | 295·1 | 89·7 | 296·9 | 94·8 |
| 70 | 301·3 | 68·5 | 302·7 | 73·6 | 304·2 | 78·8 | 305·7 | 84·0 | 307·4 | 89·3 | 309·2 | 94·6 | 311·1 | 100·0 |
| 71 | 316·6 | 72·4 | 318·0 | 77·8 | 319·5 | 83·3 | 321·2 | 88·8 | 323·0 | 94·4 | 324·9 | 100·0 | 326·9 | 105·7 |
| 72 | 335·5 | 76·7 | 335·0 | 82·5 | 336·7 | 88·3 | 338·4 | 94·1 | 340·3 | 100·0 | 342·3 | 106·0 | 344·4 | 112·0 |
| 73 | 352·5 | 81·5 | 354·1 | 87·6 | 355·8 | 93·8 | 357·7 | 100·0 | 359·6 | 106·3 | 361·7 | 112·6 | 364·0 | 119·0 |
| 74 | 373·9 | 86·9 | 375·6 | 93·4 | 377·4 | 100·0 | 379·4 | 106·6 | 381·5 | 113·3 | 383·7 | 120·1 | 386·1 | 126·9 |
| 75 | 398·2 | 93·0 | 400·0 | 100·0 | 401·9 | 107·0 | 404·0 | 114·1 | 406·3 | 121·3 | 408·6 | 128·5 | 411·2 | 135·8 |
| 76 | 426·0 | 100·0 | 427·9 | 107·5 | 430·0 | 115·1 | 432·2 | 122·6 | 434·6 | 130·3 | 437·2 | 138·1 | 439·9 | 146·0 |
| 77 | 458·2 | 108·0 | 460·2 | 116·1 | 462·5 | 124·2 | 464·8 | 132·4 | 467·4 | 140·7 | 471·2 | 149·1 | 473·1 | 157·7 |
| 78 | 495·7 | 117·3 | 497·9 | 127·6 | 500·4 | 134·9 | 502·8 | 143·8 | 505·7 | 152·9 | 508·7 | 162·0 | 511·8 | 171·2 |
| 79 | 540·1 | 118·3 | 542·6 | 137·8 | 548·2 | 147·5 | 548·0 | 157·3 | 551·1 | 167·2 | 554·3 | 177·1 | 557·7 | 187·2 |
| 80 | 593·5 | 141·1 | 596·2 | 152·0 | 599·1 | 162·6 | 602·2 | 173·4 | 605·5 | 184·3 | 609·1 | 195·3 | 612·8 | 206·4 |

| | 21° | | 22° | | 23° | | 24° | | 25° | | 26° | | 27° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 21 | 114·7 | 14·7 | | | | | | | | | | | | |
| 22 | 115·5 | 15·5 | 116·3 | 16·3 | | | | | | | | | | |
| 23 | 116·4 | 16·3 | 117·2 | 17·1 | 118·0 | 18·0 | | | | | | | | |
| 24 | 117·2 | 17·1 | 118·1 | 18·0 | 118·9 | 18·9 | 119·8 | 19·8 | | | | | | |
| 25 | 118·2 | 17·9 | 119·0 | 18·8 | 119·9 | 19·8 | 120·8 | 20·8 | 121·7 | 21·7 | | | | |
| 26 | 119·2 | 18·7 | 120·0 | 19·7 | 120·9 | 20·7 | 121·8 | 21·7 | 122·8 | 22·8 | 123·8 | 23·8 | | |
| 27 | 120·2 | 19·6 | 121·0 | 20·6 | 121·9 | 21·6 | 122·8 | 22·7 | 123·8 | 23·8 | 124·9 | 24·8 | 126·0 | 26·0 |
| 28 | 121·3 | 20·4 | 122·1 | 21·5 | 123·0 | 22·6 | 124·0 | 23·7 | 125·0 | 24·8 | 126·0 | 25·9 | 127·1 | 27·1 |

## SPHERICAL TRAVERSE TABLE.

| | 21° | | 22° | | 23° | | 24° | | 25° | | 26° | | 27° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 29 | 122·5 | 21·3 | 123·3 | 22·4 | 124·2 | 23·5 | 125·2 | 24·7 | 126·2 | 25 8 | 127·2 | 27·0 | 128·3 | 28·2 |
| 30 | 123·2 | 22·2 | 124·5 | 23·3 | 125·4 | 24·5 | 126·4 | 25·7 | 127·4 | 26·9 | 128·2 | 28·2 | 129·6 | 29·4 |
| 31 | 125·0 | 23·1 | 125·8 | 24 3 | 126·7 | 25·5 | 127·7 | 26 7 | 128·7 | 28·0 | 129·8 | 29·3 | 130·9 | 30 6 |
| 32 | 126·3 | 24·0 | 127·2 | 25·2 | 128·1 | 26·5 | 129·1 | 27·8 | 130·1 | 29·1 | 131·2 | 30·5 | 132·3 | 31·8 |
| 33 | 127·7 | 24·9 | 128·6 | 26·2 | 129·5 | 27·6 | 130·5 | 28·9 | 131·6 | 30·3 | 132·7 | 31·7 | 133·8 | 33·1 |
| 34 | 129·2 | 25·9 | 130·1 | 27·2 | 131·0 | 28·6 | 132·0 | 30·0 | 133·1 | 31·4 | 134·2 | 32·9 | 135·4 | 34·4 |
| 35 | 130·8 | 26·9 | 131·7 | 28·3 | 132·6 | 29·7 | 133 6 | 31·2 | 134·7 | 32·6 | 135·8 | 34·1 | 137·0 | 35·7 |
| 36 | 132·4 | 27·9 | 133·3 | 29·4 | 134·3 | 30·8 | 135·3 | 32·3 | 136·4 | 33 9 | 137·5 | 35·4 | 138·7 | 37·0 |
| 37 | 134·1 | 28·9 | 135·0 | 30·4 | 136·0 | 32·0 | 137·1 | 33·5 | 138·2 | 35·1 | 139·3 | 36·7 | 140·5 | 38·4 |
| 38 | 135·9 | 30·0 | 136·9 | 31·6 | 137·9 | 33·2 | 138·9 | 34·8 | 140·0 | 36·4 | 141·2 | 38·1 | 142·4 | 39·8 |
| 39 | 137·8 | 31·1 | 138·8 | 32·7 | 139·5 | 34·4 | 140·9 | 36·0 | 142·0 | 37·8 | 143·2 | 39·5 | 144·4 | 41·2 |
| 40 | 139 8 | 32·2 | 140·8 | 33·9 | 141·8 | 35 6 | 142·9 | 37·4 | 144·0 | 39·1 | 145·2 | 40·9 | 146·5 | 42·8 |
| 41 | 141·9 | 33·4 | 142·9 | 35·1 | 143 9 | 36·9 | 145 0 | 38·7 | 146 2 | 40·5 | 147·4 | 42·4 | 148·7 | 44·3 |
| 42 | 144·1 | 34·6 | 145·1 | 36·4 | 146·2 | 38·2 | 147·3 | 40·1 | 148·5 | 42·0 | 149·7 | 43·9 | 151·0 | 45·9 |
| 43 | 146·5 | 35·8 | 147·5 | 37·7 | 148·5 | 39 6 | 149·7 | 41·5 | 150·9 | 43·5 | 152·1 | 45·5 | 153·5 | 47·5 |
| 44 | 148·9 | 37·1 | 149·9 | 39·0 | 151·0 | 41·0 | 152·2 | 43·0 | 153·4 | 45 0 | 154·7 | 47·1 | 156·0 | 49·2 |
| 45 | 151·5 | 38·4 | 152·5 | 40·4 | 153·6 | 42·4 | 154·8 | 44·5 | 156·0 | 46·6 | 157·3 | 48·8 | 158·7 | 50·4 |
| 46 | 154·2 | 39·7 | 155·3 | 41·8 | 156·4 | 44·0 | 157·6 | 46·1 | 158·8 | 48·3 | 160·2 | 50·5 | 161·6 | 52·8 |
| 47 | 157·1 | 41·2 | 158·1 | 43·3 | 159·3 | 45·5 | 160·5 | 47·8 | 161·8 | 50·0 | 163·1 | 52·3 | 164·6 | 54 6 |
| 48 | 160·1 | 42·6 | 161·2 | 44·9 | 162·3 | 47·1 | 163·6 | 49·4 | 164·9 | 51·8 | 166·3 | 54·2 | 167·7 | 56 6 |
| 49 | 163·3 | 44·2 | 164·4 | 46·5 | 165·6 | 48·8 | 166·8 | 51·2 | 168·2 | 53 6 | 169·6 | 56·1 | 171·1 | 58·6 |
| 50 | 166 6 | 45·7 | 167·8 | 48·1 | 169·0 | 50·6 | 170·3 | 53·1 | 171·6 | 55 6 | 173·1 | 58·1 | 174·6 | 60·7 |
| 51 | 170·2 | 47·4 | 171·4 | 49 9 | 172·7 | 52·4 | 173·9 | 55·0 | 175·3 | 57·6 | 176·8 | 60·2 | 178·3 | 62·9 |
| 52 | 174·0 | 49·1 | 175·2 | 51·7 | 176·4 | 54·3 | 177·8 | 57·0 | 179·2 | 59·7 | 180·7 | 62·4 | 182·3 | 65·2 |
| 53 | 178·0 | 50·9 | 179·2 | 53 6 | 180·5 | 56 3 | 181·9 | 59·1 | 183·3 | 61·9 | 184·9 | 64·7 | 186·5 | 67·6 |
| 54 | 182·2 | 52·8 | 183·5 | 55·6 | 184·8 | 58·4 | 186·2 | 61·3 | 187·7 | 64·2 | 189·3 | 67·1 | 190·9 | 70·1 |
| 55 | 186·7 | 54·8 | 188·0 | 57·7 | 189·4 | 60·6 | 190·8 | 63·6 | 192·4 | 66·6 | 194·0 | 69·7 | 195·7 | 72·8 |
| 56 | 191·6 | 56·9 | 192·9 | 59·9 | 194·3 | 62·9 | 195·7 | 66·0 | 197·3 | 69·1 | 199·0 | 72·3 | 200·7 | 75·5 |
| 57 | 196·7 | 59·1 | 198·0 | 62·2 | 199·5 | 65·4 | 201·0 | 68·6 | 202·6 | 71·8 | 204·3 | 75·1 | 206·1 | 78·5 |
| 58 | 202·1 | 61·4 | 203·5 | 64·7 | 205·0 | 67·9 | 206·6 | 71·2 | 208·2 | 74·6 | 210·0 | 78·0 | 211·8 | 81·5 |
| 59 | 208·0 | 63·9 | 209·4 | 67·2 | 210·9 | 70·6 | 212·5 | 74·1 | 214·2 | 77·6 | 216·0 | 81·2 | 217·9 | 84·8 |
| 60 | 214·2 | 66·5 | 215·7 | 70·0 | 217·3 | 73·5 | 218·9 | 77·1 | 220·7 | 80·8 | 222·5 | 84·5 | 224·5 | 88·2 |
| 61 | 220·9 | 69·2 | 222·5 | 72·9 | 224·1 | 76 6 | 225·8 | 80·3 | 227·6 | 84·1 | 229·5 | 88·0 | 231·5 | 91·9 |
| 62 | 228·2 | 72·2 | 229·7 | 76·0 | 231·4 | 79·8 | 233·2 | 83·7 | 235·0 | 87·7 | 237·0 | 91·7 | 239·1 | 95·8 |
| 63 | 235·9 | 75·3 | 237·6 | 79·3 | 239·3 | 83·3 | 241·1 | 87·4 | 243·0 | 91·5 | 245·1 | 95·7 | 247·2 | 100·0 |
| 64 | 244·3 | 78·7 | 246·0 | 82·8 | 247·8 | 87·0 | 249·7 | 91·3 | 251·7 | 95·6 | 253·8 | 100·0 | 256·0 | 104·5 |
| 65 | 253·5 | 82·3 | 255·2 | 86·6 | 257·1 | 91·0 | 259·0 | 95·5 | 261·1 | 100·0 | 263·3 | 104·6 | 265·6 | 109·3 |
| 66 | 263·4 | 86·2 | 265·2 | 90·7 | 267·1 | 95·3 | 269·1 | 100·0 | 271·3 | 104·7 | 273·5 | 109·5 | 275·9 | 114·4 |
| 67 | 274·1 | 90·4 | 276·0 | 95·2 | 278·0 | 100·0 | 280·1 | 104·9 | 282·4 | 109·9 | 284·7 | 114·9 | 287·2 | 120·0 |
| 68 | 285·9 | 95·0 | 287·9 | 100·0 | 290·0 | 105·1 | 292·2 | 110·2 | 294·5 | 115·4 | 297·0 | 120·7 | 299·6 | 126·1 |
| 69 | 298·9 | 100·0 | 301·0 | 105·3 | 303·1 | 110·6 | 305·4 | 116·0 | 307·9 | 121·5 | 310·5 | 127·1 | 313·2 | 132·7 |
| 70 | 313·2 | 105·5 | 315·3 | 111·0 | 317·6 | 116·6 | 320·1 | 122·3 | 322·6 | 128·1 | 325·3 | 134·0 | 328·1 | 140·0 |
| 71 | 329·0 | 111·5 | 331·3 | 117·3 | 333·7 | 123·3 | 336·2 | 129·3 | 338·9 | 135·4 | 341·7 | 141·6 | 344·7 | 148·0 |
| 72 | 346·6 | 118·1 | 349·0 | 124·3 | 351·6 | 130·6 | 354·2 | 137·0 | 357·1 | 143·5 | 360·0 | 150·1 | 363·2 | 156·8 |
| 73 | 366·4 | 125·6 | 368·9 | 132·1 | 371·6 | 138·8 | 374·4 | 145·6 | 377·4 | 152·5 | 380·5 | 159·5 | 383·9 | 166·7 |
| 74 | 388·6 | 133·9 | 391·3 | 140·9 | 394·1 | 148·0 | 397·1 | 155·3 | 400·3 | 162·6 | 403·6 | 170·1 | 407·2 | 177·7 |
| 75 | 413·9 | 143·3 | 416·7 | 150·8 | 419·7 | 158·4 | 422·9 | 166·5 | 426·3 | 174·0 | 429·9 | 182·0 | 432·6 | 190·2 |
| 76 | 442·8 | 154·0 | 445·8 | 162·0 | 449·0 | 170·3 | 452·5 | 178·6 | 456·1 | 187·0 | 459·9 | 195·6 | 463·9 | 204·4 |
| 77 | 476·2 | 166·3 | 479·4 | 175·0 | 482·9 | 183·9 | 486·6 | 192·8 | 490·5 | 202·0 | 494·6 | 211·3 | 498·9 | 220·7 |
| 78 | 515·2 | 180·6 | 518·7 | 190·9 | 522·5 | 199·7 | 526·5 | 209·5 | 530·7 | 219·4 | 535·1 | 229·5 | 539·8 | 239·7 |
| 79 | 561·4 | 197·5 | 565·3 | 207·8 | 569·3 | 218·4 | 573·7 | 229·1 | 578·3 | 239·9 | 583·1 | 250·9 | 588·2 | 262·1 |
| 80 | 616·9 | 217·7 | 621·1 | 229·1 | 625·6 | 240·7 | 630·4 | 252·5 | 635·4 | 264·5 | 610·7 | 276·6 | 646·3 | 289·0 |

| | 28° | | 29° | | 30° | | 31° | | 32° | | 33° | | 34° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 28 | 128·3 | 28·3 | | | | | | | | | | | | |
| 29 | 129·5 | 29·5 | 130·7 | 30·7 | | | | | | | | | | |
| 30 | 130·8 | 30·7 | 132·0 | 32·0 | 133·3 | 33·3 | | | | | | | | |
| 31 | 132·1 | 31·9 | 133·4 | 33·3 | 134·7 | 34·7 | 136·1 | 36·1 | | | | | | |
| 32 | 133·5 | 33·2 | 134·8 | 34·6 | 136·2 | 36·1 | 137·6 | 37·5 | 139·0 | 39·0 | | | | |
| 33 | 135·0 | 34·5 | 136·3 | 36·0 | 137·7 | 37·5 | 139·1 | 39·0 | 140·6 | 40·6 | 142·2 | 42·2 | | |

## SPHERICAL TRAVERSE TABLE.

| | 28° | | 29° | | 30° | | 31° | | 32° | | 33° | | 34° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 34 | 136 6 | 35·9 | 137·9 | 37·4 | 139·3 | 38·9 | 140·7 | 40·5 | 142·2 | 42·1 | 143·8 | 43·8 | 145·5 | 45·5 |
| 35 | 138·3 | 37·2 | 139·6 | 38·8 | 141·0 | 40·4 | 142·4 | 42·1 | 143·9 | 43·8 | 145·6 | 45·5 | 147·3 | 47·2 |
| 36 | 140·0 | 38·6 | 141·3 | 40·3 | 142·7 | 41·9 | 144·2 | 43·7 | 145·8 | 45·4 | 147·4 | 47·2 | 149·1 | 49·0 |
| 37 | 141·8 | 40·1 | 143·2 | 41·8 | 144·6 | 43·5 | 146·1 | 45·3 | 147·6 | 47·1 | 149·3 | 48·9 | 151·0 | 50·8 |
| 38 | 143·7 | 41·5 | 145·1 | 43·3 | 146·5 | 45·1 | 148·0 | 46·9 | 149·6 | 48·8 | 151·3 | 50·7 | 153·1 | 52·7 |
| 39 | 145·7 | 43·1 | 147·1 | 44·9 | 148·6 | 46·7 | 150·1 | 48·7 | 151·7 | 50·6 | 153·4 | 52·6 | 155·2 | 54·6 |
| 40 | 147·8 | 44·6 | 149·3 | 46 5 | 150·7 | 48·4 | 152·3 | 50·4 | 153·9 | 52·4 | 155·7 | 54·5 | 157·5 | 56·6 |
| 41 | 150·1 | 46·2 | 151·5 | 48·2 | 153·0 | 50·2 | 154·6 | 52·2 | 156·2 | 54 3 | 158·0 | 56·4 | 159·8 | 58·6 |
| 42 | 152·4 | 47·9 | 153·9 | 49·9 | 155·4 | 52·0 | 157·0 | 54·1 | 158·7 | 56·3 | 160·4 | 58·5 | 162·3 | 60·8 |
| 43 | 154·9 | 49·6 | 156·3 | 51·7 | 157·9 | 53·8 | 159·5 | 56·0 | 161·2 | 58·3 | 163 0 | 60·6 | 164·9 | 62·9 |
| 44 | 157 5 | 51·3 | 158·9 | 53 5 | 160·5 | 55·8 | 162·2 | 58·0 | 163·9 | 60·3 | 165·8 | 62·7 | 167·7 | 65·1 |
| 45 | 160·2 | 53·2 | 161·7 | 55·4 | 163·3 | 57·7 | 165·0 | 60·1 | 166·8 | 62·5 | 168·6 | 64·9 | 170·6 | 67·4 |
| 46 | 163·0 | 55·1 | 164·6 | 57·4 | 166·2 | 59·8 | 167·9 | 62·2 | 169·7 | 64·7 | 171·6 | 67·2 | 173·6 | 69·8 |
| 47 | 166·1 | 57·0 | 167·6 | 59·4 | 169·3 | 61·9 | 171·1 | 64·4 | 172·9 | 67·0 | 174·8 | 69·6 | 176·9 | 72·3 |
| 48 | 169·3 | 59·0 | 170·9 | 61·6 | 172·6 | 64·1 | 174·3 | 66·7 | 176·2 | 69·4 | 178·2 | 72·1 | 180·3 | 74·9 |
| 49 | 172·6 | 61·2 | 174·3 | 63·8 | 176·0 | 66·4 | 177·8 | 69·1 | 179·7 | 71·9 | 181·7 | 74·7 | 183·9 | 77·6 |
| 50 | 176·2 | 63·4 | 177·9 | 66·1 | 179·1 | 68·8 | 181·5 | 71·6 | 183·4 | 74·5 | 185·5 | 77·4 | 187·7 | 80·4 |
| 51 | 180·0 | 65·7 | 181·7 | 68·4 | 183·5 | 70·3 | 185·4 | 74 2 | 187·4 | 77·2 | 189·5 | 80·2 | 191·7 | 83·3 |
| 52 | 184·0 | 68·1 | 185·7 | 70·9 | 187·6 | 73·9 | 189·5 | 76·9 | 191·5 | 80·0 | 193·7 | 83·1 | 195·9 | 86·3 |
| 53 | 188·2 | 70·6 | 190·0 | 73·6 | 191·9 | 76·6 | 193·8 | 79·7 | 195·9 | 82·9 | 198·1 | 86·2 | 200·4 | 89·5 |
| 54 | 192·7 | 73·2 | 194·5 | 76·3 | 196·4 | 79·5 | 198·5 | 82·7 | 200·6 | 86·0 | 202·9 | 89·4 | 205·2 | 92·8 |
| 55 | 197·5 | 75·9 | 199·3 | 79·2 | 201·3 | 82·4 | 203·4 | 85·8 | 205·6 | 89·2 | 207·9 | 92·7 | 210·3 | 96·3 |
| 56 | 202·5 | 78·8 | 204·5 | 82·2 | 206·5 | 85·6 | 208·6 | 89·1 | 210·9 | 92·6 | 213·2 | 96·3 | 215·7 | 100·0 |
| 57 | 207·9 | 80·0 | 209·9 | 85·4 | 212·0 | 88·9 | 214·2 | 92·5 | 216·6 | 96·2 | 218·9 | 100·0 | 221·5 | 103·9 |
| 58 | 213·7 | 85·1 | 215·8 | 88·7 | 217·9 | 92·4 | 220·2 | 96·2 | 222·5 | 100·0 | 225·0 | 103·9 | 227·6 | 107·9 |
| 59 | 219·9 | 88·5 | 222·0 | 92·2 | 224·2 | 96·1 | 226·5 | 100·0 | 228·9 | 104·0 | 231·5 | 108·1 | 234·2 | 112·3 |
| 60 | 226 5 | 92·1 | 228·7 | 96·0 | 230·9 | 100·0 | 233·3 | 104·1 | 235·8 | 108·2 | 238·5 | 112·5 | 241·2 | 116·8 |
| 61 | 233·6 | 95·9 | 235·8 | 100·0 | 238·2 | 104·2 | 240·6 | 108·4 | 243·2 | 112·7 | 245·9 | 117·2 | 248·8 | 121·7 |
| 62 | 241·2 | 100·0 | 243·5 | 104·2 | 246·0 | 108·6 | 248·5 | 113·0 | 251·2 | 117·5 | 254·0 | 122·1 | 256·9 | 126·9 |
| 63 | 249·5 | 104·3 | 251·8 | 108·8 | 254·3 | 113·3 | 257·0 | 117·9 | 259·7 | 122·6 | 262·6 | 127·5 | 265·7 | 132·4 |
| 64 | 258·4 | 109·0 | 260·8 | 113·6 | 263·4 | 118·4 | 266·1 | 123·2 | 269·0 | 128·1 | 272·0 | 133·1 | 275·2 | 138·3 |
| 65 | 268·0 | 114·0 | 270·5 | 118·9 | 273·2 | 123·8 | 276·0 | 128·9 | 279·0 | 134·0 | 282·1 | 139·3 | 285·4 | 144·6 |
| 66 | 278·5 | 119·4 | 281·1 | 124·5 | 283·9 | 129·7 | 286·8 | 135·0 | 289·9 | 140·3 | 293·2 | 145·9 | 296·6 | 151·5 |
| 67 | 289·9 | 125·3 | 292·6 | 130·6 | 295·5 | 136·0 | 298·6 | 141·6 | 301·8 | 147·2 | 305·2 | 153·0 | 308·6 | 158·9 |
| 68 | 302·3 | 131·6 | 305·2 | 137·2 | 308·2 | 142·9 | 311·4 | 148·7 | 314·8 | 154·7 | 318·3 | 160·7 | 322·0 | 167·0 |
| 69 | 316·0 | 138·5 | 319·0 | 144·4 | 322·2 | 150·4 | 325·5 | 156·5 | 329·0 | 162·8 | 332·7 | 169·2 | 336·6 | 175·7 |
| 70 | 331·1 | 146·1 | 334·3 | 152·3 | 337·6 | 158·6 | 341·1 | 165·1 | 344·8 | 171·7 | 348·6 | 178·4 | 352·7 | 185·3 |
| 71 | 347·9 | 154·4 | 351·2 | 161·0 | 354·7 | 167·7 | 358·3 | 174·5 | 362·2 | 181·5 | 366·2 | 188·6 | 370·5 | 195·9 |
| 72 | 366·5 | 163·6 | 370·0 | 170·6 | 373·7 | 177·7 | 377·5 | 184·9 | 381·6 | 192·3 | 385·9 | 199·9 | 390·3 | 207·6 |
| 73 | 387·4 | 173·9 | 391·1 | 181·3 | 394·9 | 188·8 | 399·0 | 196·5 | 403·3 | 204·4 | 407·8 | 212·4 | 412·6 | 220·6 |
| 74 | 410·9 | 185·4 | 414·8 | 193·9 | 413·9 | 201·3 | 423·2 | 209·5 | 427·8 | 217·9 | 432·6 | 226·5 | 437·6 | 235·2 |
| 75 | 437·6 | 198·4 | 441·8 | 206·8 | 446·1 | 215·5 | 450·7 | 224·2 | 455·6 | 234·3 | 460·7 | 242·4 | 466·0 | 251·7 |
| 76 | 468·2 | 213·3 | 472·6 | 222·3 | 477·3 | 231·6 | 482·2 | 241·0 | 487·4 | 250·6 | 492·9 | 260·5 | 498·6 | 270·5 |
| 77 | 503·5 | 230·3 | 508·3 | 240·1 | 513·3 | 250·1 | 518·6 | 260·3 | 524·2 | 270·7 | 530·1 | 281·3 | 536·2 | 292·1 |
| 78 | 544·7 | 250·1 | 549·9 | 260·8 | 555·4 | 271·6 | 561·1 | 282·9 | 567·2 | 294·0 | 573·5 | 305·5 | 580·2 | 317·3 |
| 79 | 593·6 | 273·5 | 599·2 | 285·2 | 605·2 | 297·0 | 611·4 | 309·1 | 618·0 | 321·5 | 624·9 | 334·1 | 632·2 | 347·0 |
| 80 | 652·2 | 301·5 | 658·4 | 314·4 | 665·0 | 327·4 | 671·8 | 340·8 | 679·0 | 354·4 | 686·7 | 368·3 | 694·6 | 382·5 |

| | 35° | | 36° | | 37° | | 38° | | 39° | | 40° | | 41° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 35 | 149·0 | 49·0 | | | | | | | | | | | | |
| 36 | 150·9 | 50·9 | 152·8 | 52·8 | | | | | | | | | | |
| 37 | 152·9 | 52·8 | 154·8 | 54·7 | 156·8 | 56·8 | | | | | | | | |
| 38 | 154·9 | 54·7 | 156·9 | 56·8 | 158·9 | 58·9 | 161·0 | 61·0 | | | | | | |
| 39 | 157·1 | 56·7 | 159·0 | 58·8 | 161·1 | 61·0 | 163·3 | 63·3 | 165·6 | 65·6 | | | | |
| 40 | 159·4 | 58·8 | 161·4 | 61·0 | 163·5 | 63·2 | 165·7 | 65·6 | 168·0 | 67·9 | 170·4 | 70·4 | | |
| 41 | 161·8 | 60·9 | 163·8 | 63·2 | 166·0 | 65·5 | 168·1 | 67·9 | 170·5 | 70·4 | 173·0 | 72·9 | 175·6 | 75·6 |
| 42 | 164·3 | 63·0 | 166·3 | 65·4 | 168·2 | 67·8 | 170·8 | 70·3 | 173·1 | 72·9 | 175·7 | 75·5 | 178·4 | 78·3 |
| 43 | 166·9 | 65·3 | 169·0 | 67·7 | 171·2 | 70·3 | 173·5 | 72·9 | 175·9 | 75·5 | 178·5 | 78·2 | 181·2 | 81·1 |
| 44 | 169·7 | 67·6 | 171·8 | 70·2 | 174·1 | 72·8 | 176·4 | 75·4 | 178·9 | 78·2 | 181·5 | 81·0 | 184·2 | 83·9 |

## SPHERICAL TRAVERSE TABLE.

| | 35° | | 36° | | 37° | | 38° | | 39° | | 40° | | 41° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 45 | 172·6 | 70·0 | 174·8 | 72·7 | 177·1 | 75·4 | 179·5 | 78·1 | 182·0 | 81·0 | 184·6 | 83·9 | 187·4 | 86·9 |
| 46 | 176·7 | 72·5 | 177·9 | 75·2 | 180·2 | 78·0 | 182·7 | 80·9 | 185·2 | 83·9 | 187·9 | 86·9 | 190·7 | 90·0 |
| 47 | 179·0 | 75·1 | 181·2 | 77·9 | 183·6 | 80·8 | 186·1 | 83·8 | 188·7 | 86·8 | 191·4 | 90·0 | 194·3 | 93·2 |
| 48 | 182·5 | 77·8 | 184·7 | 80·7 | 187·1 | 83·7 | 189·6 | 86·8 | 192·3 | 89·9 | 195·1 | 93·2 | 198·0 | 96·5 |
| 49 | 186·1 | 80·5 | 188·4 | 83·6 | 190·9 | 86·7 | 192·4 | 89·9 | 196·1 | 93·2 | 199·0 | 96·5 | 202·0 | 100·0 |
| 50 | 189·9 | 83·4 | 192·3 | 86·6 | 194 8 | 89·8 | 197·4 | 93·1 | 200·2 | 96·5 | 203·1 | 100·0 | 206·1 | 103·6 |
| 51 | 194·0 | 86·5 | 196·4 | 89 7 | 199·0 | 93·1 | 201·6 | 96·5 | 204·5 | 100·0 | 207·4 | 103·6 | 210·5 | 107·3 |
| 52 | 198·3 | 89·6 | 200·0 | 93·0 | 203·4 | 96·4 | 206·1 | 100·0 | 209·0 | 103·6 | 212·0 | 107·4 | 215·2 | 111·3 |
| 53 | 202·8 | 92·9 | 205·4 | 96·4 | 208·1 | 100·0 | 210·9 | 103·7 | 213·8 | 107·5 | 216·9 | 111·3 | 220·2 | 115·4 |
| 54 | 207·7 | 96·4 | 210·3 | 100·0 | 213·0 | 103·7 | 215·9 | 107·5 | 218·9 | 111·5 | 222·1 | 115·5 | 225·4 | 119·6 |
| 55 | 212·8 | 100·0 | 215·5 | 103·8 | 218·3 | 107·6 | 221·2 | 111·6 | 224·3 | 115·6 | 227·6 | 119·8 | 231·0 | 124·1 |
| 56 | 218·3 | 103·8 | 221·0 | 107·7 | 223·9 | 111·7 | 226·9 | 115·8 | 230·1 | 120·1 | 233·4 | 124·4 | 237·0 | 128·9 |
| 57 | 224·1 | 107·8 | 226 9 | 111·9 | 229·9 | 116·0 | 233·0 | 120·3 | 236·3 | 124·7 | 239·7 | 129·2 | 243·3 | 133·9 |
| 58 | 230·4 | 112·1 | 233·3 | 116·3 | 236·3 | 120·6 | 239·5 | 125·0 | 242·8 | 129·6 | 246·3 | 134·3 | 250·0 | 139·1 |
| 59 | 237·0 | 116·5 | 240·0 | 121·0 | 243·1 | 125·4 | 246·4 | 130·0 | 249·8 | 134·8 | 253·5 | 139·7 | 257·3 | 144·7 |
| 60 | 244·2 | 121·3 | 247·2 | 125·8 | 250·4 | 130·5 | 253·8 | 135·3 | 257·4 | 140·3 | 261·1 | 145·3 | 265·0 | 150·6 |
| 61 | 251·8 | 126·3 | 255·0 | 131·1 | 258·3 | 135·9 | 261·8 | 140·9 | 265·4 | 146·1 | 269·3 | 151·4 | 273·3 | 156·8 |
| 62 | 260·0 | 131·7 | 263·2 | 136·6 | 266·7 | 141·7 | 270·3 | 146·9 | 274·1 | 152·3 | 278·1 | 157·8 | 282·2 | 163·5 |
| 63 | 268·9 | 137·4 | 272·3 | 142·6 | 275·8 | 147·9 | 279·5 | 153·3 | 283·4 | 158·9 | 287·5 | 164·7 | 291·9 | 170·6 |
| 64 | 278·5 | 143·6 | 282·0 | 149·0 | 285·6 | 154·5 | 289·5 | 160·2 | 293·5 | 166·0 | 297·8 | 172·0 | 302·3 | 178·2 |
| 65 | 288·9 | 150·2 | 292·4 | 155·8 | 296·3 | 161·6 | 300·3 | 167·5 | 304·5 | 173·7 | 308·9 | 179·9 | 313·5 | 186·4 |
| 66 | 300·1 | 157·3 | 303·9 | 163·2 | 307·9 | 169·2 | 312·0 | 175·5 | 316·4 | 181·9 | 321·0 | 188·5 | 325·8 | 195·2 |
| 67 | 312·4 | 165·0 | 316·3 | 171·2 | 320·5 | 177·5 | 324·8 | 184·1 | 329·3 | 190·8 | 334·1 | 197·7 | 339·1 | 204·8 |
| 68 | 325·9 | 173·3 | 330·0 | 179·8 | 334·2 | 186·5 | 338·8 | 193·4 | 343·5 | 200·4 | 348·5 | 207·7 | 353·7 | 215·1 |
| 69 | 340·7 | 182·4 | 344·9 | 189·3 | 349·4 | 196 3 | 354·1 | 203·5 | 359·1 | 211·0 | 364·3 | 218·6 | 369·7 | 226·5 |
| 70 | 356·9 | 192·4 | 361·4 | 199·6 | 366 1 | 207·0 | 371·0 | 214·6 | 376·2 | 222·5 | 381·7 | 230·5 | 387·4 | 238·8 |
| 71 | 375·0 | 203·4 | 379·7 | 211·0 | 384 6 | 218·8 | 389 8 | 226·9 | 395·2 | 235·2 | 401·0 | 243·7 | 407·0 | 252·5 |
| 72 | 395·1 | 215·5 | 400 0 | 223 6 | 405·2 | 231·9 | 410·7 | 240·5 | 416·4 | 249·2 | 422·4 | 258·2 | 428·8 | 267·5 |
| 73 | 417·5 | 229·0 | 422 8 | 237 6 | 428·3 | 246·5 | 434·0 | 255·5 | 440·1 | 264·9 | 446·5 | 274·5 | 453·2 | 284·3 |
| 74 | 442·9 | 244·2 | 448·4 | 253·4 | 454·3 | 262·8 | 460·4 | 272·5 | 466·8 | 282·4 | 473·6 | 292·6 | 480·7 | 303·2 |
| 75 | 471·7 | 261·3 | 477·6 | 271·1 | 483 8 | 281·2 | 490·3 | 291·6 | 497·2 | 302·2 | 504·4 | 313·3 | 511·9 | 324·5 |
| 76 | 504·6 | 280·8 | 510·9 | 291·4 | 517·6 | 302·2 | 524·6 | 313·4 | 531·9 | 324·8 | 539·6 | 336·5 | 547·7 | 348·7 |
| 77 | 542·7 | 303·3 | 549 5 | 314·7 | 556 6 | 326·4 | 564·1 | 338·4 | 572·0 | 350·8 | 580·3 | 363·5 | 589·0 | 376·5 |
| 78 | 587·2 | 329·4 | 594 5 | 341·8 | 602·2 | 354 5 | 610·4 | 367·6 | 618·9 | 381·0 | 627·9 | 394·8 | 637·3 | 409·0 |
| 79 | 639·8 | 360·2 | 647 8 | 373·8 | 656·2 | 387·7 | 665·1 | 401·9 | 674·4 | 416·6 | 684·1 | 431·7 | 694·4 | 447·2 |
| 80 | 703·0 | 397·1 | 711·8 | 412·1 | 721·1 | 427·4 | 730·8 | 443·1 | 741·0 | 459·2 | 751·8 | 475·9 | 763·0 | 493·0 |

| | 42° | | 43° | | 44° | | 45° | | 46° | | 47° | | 48° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 42 | 181·1 | 81·1 | | | | | | | | | | | | |
| 43 | 184·0 | 84·0 | 187·0 | 87·0 | | | | | | | | | | |
| 44 | 187·1 | 86·9 | 190·1 | 90·0 | 193·3 | 93·3 | | | | | | | | |
| 45 | 190·3 | 90·0 | 193·4 | 93·3 | 196·6 | 96·6 | 200·0 | 100·0 | | | | | | |
| 46 | 193·7 | 93·2 | 196 8 | 96·6 | 200·1 | 100·0 | 203·6 | 103·5 | 207·2 | 107·2 | | | | |
| 47 | 197·3 | 96·6 | 200·5 | 100·0 | 203·8 | 103 6 | 207·4 | 107·2 | 211·1 | 111·0 | 215·0 | 115·0 | | |
| 48 | 201·1 | 100·0 | 204·3 | 103·6 | 207·8 | 107·3 | 211·3 | 111·1 | 215·1 | 115·0 | 219·1 | 119·1 | 223·3 | 123·3 |
| 49 | 205·1 | 103·6 | 208·4 | 107·3 | 211·9 | 111·1 | 215·6 | 115·0 | 219·4 | 119·1 | 223·5 | 123·4 | 227·8 | 127·8 |
| 50 | 209·3 | 107·3 | 212·7 | 111·1 | 216·3 | 115·1 | 220·0 | 119·2 | 224·0 | 123·4 | 228·2 | 127·8 | 232·5 | 132·4 |
| 51 | 213·8 | 111·2 | 217·3 | 115·2 | 220·9 | 119·3 | 224·7 | 123·5 | 228·7 | 127·9 | 233·0 | 132·4 | 237·5 | 137·2 |
| 52 | 218·6 | 115·2 | 222·1 | 119·4 | 225·8 | 123·6 | 229·7 | 128·0 | 233·8 | 132·5 | 238·2 | 137·3 | 242·7 | 142·2 |
| 53 | 223 6 | 119·5 | 227·2 | 123·7 | 231·0 | 128·2 | 235·0 | 132·7 | 239·2 | 137·4 | 243·6 | 142·3 | 248·3 | 147·4 |
| 54 | 228·9 | 123·9 | 232·6 | 128·3 | 236·5 | 132·9 | 240·6 | 137·6 | 244·9 | 142·5 | 249·5 | 147·6 | 254·3 | 152·9 |
| 55 | 234·6 | 128·6 | 238·4 | 133·2 | 242·4 | 137·9 | 246·6 | 142·8 | 251·0 | 147·9 | 255·6 | 153·1 | 260·6 | 158·6 |
| 56 | 240·6 | 133·5 | 244·5 | 138·2 | 248·6 | 143·2 | 252·9 | 148·3 | 257·4 | 153·5 | 262·2 | 159·0 | 267·3 | 164·7 |
| 57 | 247·7 | 138·6 | 251·0 | 143·6 | 255·2 | 148·7 | 259·7 | 154·0 | 264·3 | 159·5 | 269·2 | 165·1 | 274·4 | 171·0 |
| 58 | 253·9 | 144·1 | 258·0 | 149·2 | 262·3 | 154·5 | 266·9 | 160·0 | 271·7 | 165·7 | 276·7 | 171·6 | 282·0 | 177·7 |
| 59 | 261·3 | 149·9 | 265·5 | 155·2 | 269·9 | 160·7 | 274·6 | 166·4 | 279·5 | 172·3 | 284·7 | 178·5 | 290·2 | 184·8 |
| 60 | 269·1 | 156 0 | 273·5 | 161·5 | 278·0 | 167·3 | 282·8 | 173·2 | 287·9 | 179·4 | 293·3 | 185·7 | 298·9 | 192·4 |
| 61 | 277·6 | 162·4 | 282·0 | 168·2 | 286·7 | 174·2 | 291·7 | 189·4 | 296·9 | 186·8 | 302·4 | 193·5 | 308·3 | 200.4 |

## SPHERICAL TRAVERSE TABLE.

| | 42° | | 43° | | 44° | | 45° | | 46° | | 47° | | 48° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 62 | 286·6 | 169·3 | 291·2 | 175·4 | 296·1 | 181·6 | 301·2 | 188·1 | 306·6 | 194·8 | 312·3 | 201·7 | 318·3 | 208·9 |
| 63 | 296·4 | 176·7 | 301·2 | 183·0 | 306·2 | 189·5 | 311·5 | 196·3 | 317·1 | 203·2 | 323·0 | 210·5 | 329·2 | 218·0 |
| 64 | 307·0 | 184·6 | 311·9 | 191·2 | 317·3 | 198·0 | 322·6 | 205·0 | 328·4 | 212·3 | 334·5 | 219·9 | 340·9 | 227·7 |
| 65 | 318·4 | 193·1 | 323·5 | 200·0 | 328·9 | 207·1 | 334·6 | 214·4 | 340·6 | 222·1 | 347·0 | 230·0 | 353·6 | 238·2 |
| 66 | 330·8 | 202·2 | 336·2 | 209·4 | 341·8 | 216·9 | 347·7 | 224·6 | 353·9 | 232·6 | 360·5 | 240·9 | 367·4 | 249·5 |
| 67 | 344·4 | 212·1 | 349·9 | 219·7 | 355·8 | 227·5 | 361·9 | 235·6 | 368·4 | 244·0 | 375·3 | 252·6 | 382·5 | 261·7 |
| 68 | 359·2 | 222·9 | 365·1 | 230·8 | 371·1 | 239·0 | 377·5 | 247·5 | 384·3 | 256·3 | 391·4 | 265·4 | 398·9 | 274·9 |
| 69 | 375·5 | 234·6 | 381·5 | 242·9 | 387·9 | 251·6 | 394·6 | 260·5 | 401·7 | 269·8 | 409·2 | 279·4 | 417·0 | 289·3 |
| 70 | 393·4 | 247·4 | 399·8 | 256·2 | 406·5 | 265·3 | 413·5 | 274·7 | 420·9 | 284·5 | 428·7 | 294·6 | 437·0 | 305·1 |
| 71 | 413·3 | 261·5 | 420·0 | 270·8 | 427·0 | 280·5 | 434·4 | 290·4 | 442·2 | 300·7 | 450·4 | 311·4 | 459·0 | 322·6 |
| 72 | 435·5 | 277·1 | 442·5 | 287·0 | 449·9 | 297·2 | 457·6 | 307·8 | 465·9 | 318·7 | 474·5 | 330·0 | 483·6 | 341·8 |
| 73 | 460·2 | 294·5 | 467·7 | 305·0 | 475·5 | 315·9 | 483·7 | 327.1 | 492·4 | 338·7 | 501·5 | 350·8 | 511·2 | 363·3 |
| 74 | 488·2 | 314·0 | 496·1 | 325·2 | 504·3 | 336·8 | 513·1 | 348·7 | 522·3 | 361·1 | 532·0 | 374·0 | 542·2 | 387·3 |
| 75 | 519·9 | 336·2 | 528·3 | 348·0 | 537·1 | 360·4 | 546·4 | 373·2 | 556·2 | 386·5 | 566·5 | 400·2 | 577·4 | 414·5 |
| 76 | 556·2 | 361·1 | 565·2 | 374·0 | 574·6 | 387·3 | 584·6 | 401·1 | 595·0 | 415·3 | 606·1 | 430·1 | 617·7 | 445·5 |
| 77 | 598·2 | 390·0 | 607·8 | 403·9 | 618·0 | 418·3 | 628·7 | 433·2 | 639·9 | 448·5 | 651·8 | 464·5 | 664·4 | 481·1 |
| 78 | 647·2 | 423·6 | 657·6 | 438·7 | 668·6 | 453·4 | 680·2 | 470·5 | 692·4 | 487·2 | 705·2 | 504·5 | 718·8 | 522·5 |
| 79 | 705·2 | 463·2 | 716·6 | 479·7 | 728·6 | 496·8 | 741·2 | 514·5 | 754·4 | 532·7 | 768·5 | 551·7 | 783·2 | 571·4 |
| 80 | 774·9 | 510·6 | 787·4 | 528·9 | 800·6 | 547·7 | 814·4 | 567·1 | 829·0 | 587·3 | 844·4 | 608·2 | 860·6 | 629·9 |

| | 49° | | 50° | | 51° | | 52° | | 53° | | 54° | | 55° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 49 | 232·3 | 132·3 | | | | | | | | | | | | |
| 50 | 237·1 | 137·1 | 242·0 | 142·0 | | | | | | | | | | |
| 51 | 242·2 | 142·1 | 247·2 | 147·2 | 252·5 | 152·5 | | | | | | | | |
| 52 | 247·6 | 147·2 | 252·7 | 152·5 | 258·1 | 158·1 | 263.8 | 163·8 | | | | | | |
| 53 | 253·3 | 152·7 | 258·5 | 158·2 | 264·0 | 163·9 | 269·9 | 169·9 | 276·1 | 176·1 | | | | |
| 54 | 259·3 | 158·3 | 264·7 | 164·0 | 270·3 | 170·0 | 276·3 | 176·2 | 282·7 | 182·7 | 289·4 | 189·4 | | |
| 55 | 265·7 | 164·3 | 271·2 | 170·2 | 277·0 | 176·4 | 283·2 | 182·8 | 289·7 | 189·5 | 296·6 | 196·6 | 304·0 | 204·0 |
| 56 | 272·6 | 170·5 | 278·2 | 176·7 | 284·2 | 183·1 | 290·5 | 189·8 | 297·2 | 196·7 | 304·2 | 204·1 | 311·8 | 211·7 |
| 57 | 279·9 | 177·1 | 285·6 | 183·5 | 291·8 | 190·2 | 298·2 | 197·1 | 305·1 | 204·3 | 312·4 | 211·9 | 320·1 | 219·9 |
| 58 | 287 6 | 184·1 | 293·6 | 190·7 | 299·9 | 197·6 | 306·5 | 204·8 | 313·6 | 212·4 | 321·0 | 220·3 | 329·0 | 228·5 |
| 59 | 296·0 | 191·5 | 302·1 | 198·3 | 308·5 | 205·5 | 315·4 | 213·0 | 322·6 | 220·9 | 330·3 | 229·1 | 338·5 | 237·7 |
| 60 | 304·9 | 199·2 | 311·1 | 206·4 | 317·8 | 213·9 | 324·9 | 221·7 | 332·3 | 229·9 | 340·3 | 238·4 | 348·7 | 247·4 |
| 61 | 314·4 | 207·5 | 320·9 | 215·0 | 327·8 | 222·8 | 335·0 | 230·9 | 342·7 | 239·4 | 350·9 | 248·3 | 359·6 | 257·6 |
| 62 | 324·7 | 216·4 | 331·4 | 224·1 | 338·5 | 232·3 | 346·0 | 240·7 | 353·9 | 249·6 | 362·4 | 258·9 | 371·3 | 268·6 |
| 63 | 335·7 | 225·8 | 342·7 | 233·9 | 350·0 | 242·4 | 357·8 | 251·2 | 366·0 | 260·4 | 374·7 | 270·1 | 384·0 | 280·3 |
| 64 | 347·7 | 235·9 | 354·9 | 244·3 | 362·5 | 253·2 | 370·5 | 262·4 | 379·1 | 272·1 | 388·1 | 282·2 | 397·7 | 292·8 |
| 65 | 360 7 | 246·7 | 368·1 | 255·6 | 376·0 | 264·8 | 384·3 | 274·5 | 393·2 | 284·6 | 402·6 | 295·2 | 412·5 | 306·3 |
| 66 | 374·8 | 258·4 | 382·5 | 267·7 | 390·6 | 277·4 | 399·3 | 287·5 | 408·5 | 298·1 | 418·3 | 309·1 | 418·9 | 320·8 |
| 67 | 390·1 | 271·0 | 398·2 | 280·8 | 406·6 | 290·9 | 415·7 | 301·5 | 425·3 | 312·6 | 435·4 | 324·3 | 446·2 | 336·4 |
| 68 | 406·9 | 284·7 | 415·3 | 295·0 | 424·1 | 305·6 | 433·6 | 316·8 | 443·6 | 328·5 | 454·2 | 340·7 | 465·4 | 353·5 |
| 69 | 425·3 | 299·7 | 434·1 | 310·5 | 443·3 | 321·7 | 453·2 | 333·4 | 463·7 | 345·7 | 474·7 | 358·6 | 486·5 | 372·0 |
| 70 | 445·7 | 316·1 | 454·9 | 327·2 | 464·6 | 339·3 | 474·9 | 351·7 | 485·8 | 364·6 | 497·4 | 378·2 | 509·8 | 392·4 |
| 71 | 468·2 | 334·1 | 477·8 | 346·1 | 488·1 | 358·6 | 498·9 | 371·7 | 510·4 | 385·4 | 522·6 | 399·7 | 535·5 | 414 8 |
| 72 | 493·3 | 354·0 | 503·4 | 366·8 | 514·2 | 380·1 | 525·6 | 393·9 | 537·7 | 408·4 | 550·6 | 423·6 | 564·2 | 439·5 |
| 73 | 521·3 | 376·3 | 532·1 | 389·8 | 543·5 | 403·9 | 555·5 | 418·6 | 568·3 | 434·1 | 581·9 | 450·2 | 596·3 | 467·1 |
| 74 | 553·0 | 401·2 | 564·4 | 415·6 | 576·5 | 430·7 | 589·3 | 446·4 | 602·8 | 462·8 | 617·2 | 480·0 | 632·5 | 498·0 |
| 75 | 588·9 | 429·3 | 601·1 | 444·8 | 613·9 | 460·9 | 627·6 | 477·7 | 642·0 | 495·3 | 657·3 | 513·7 | 673·6 | 533·0 |
| 76 | 630·1 | 461·4 | 643·1 | 478·0 | 656·8 | 495·3 | 671·4 | 513·4 | 686·8 | 532·3 | 703·2 | 552·0 | 720·7 | 572·8 |
| 77 | 677·6 | 498·3 | 691·6 | 516·2 | 706·4 | 534·9 | 722·1 | 554·4 | 738·7 | 574·8 | 756·3 | 596·2 | 775·0 | 618·6 |
| 78 | 733·1 | 541·2 | 748·3 | 560·7 | 764·3 | 581·0 | 781·2 | 602·2 | 799·2 | 624·3 | 818·3 | 647·5 | 838·6 | 671·5 |
| 79 | 798·8 | 591·8 | 815·3 | 613·1 | 832·8 | 635·3 | 851·3 | 658·5 | 870·8 | 682·7 | 891·6 | 708·1 | 913·7 | 734.7 |
| 80 | 877·8 | 652·4 | 895·9 | 675·9 | 915·1 | 700·3 | 935·4 | 725·9 | 950·6 | 752·6 | 979·7 | 780·6 | 1004 | 809·9 |

## SPHERICAL TRAVERSE TABLE.

| | 56° | | 57° | | 58° | | 59° | | 60° | | 61° | | 62° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 56 | 319·8 | 219 8 | | | | | | | | | | | | |
| 57 | 328·3 | 228·3 | 337·1 | 237·2 | | | | | | | | | | |
| 58 | 337·5 | 237·3 | 346·5 | 246 4 | 356·1 | 256·1 | | | | | | | | |
| 59 | 347·2 | 246·7 | 356 5 | 256 3 | 366·4 | 266·3 | 377·0 | 277·0 | | | | | | |
| 60 | 357·7 | 256 8 | 367·2 | 266·1 | 377·4 | 277·2 | 383·3 | 288·3 | 400·0 | 300·0 | | | | |
| 61 | 368 9 | 267 5 | 378·7 | 277·8 | 389·5 | 288·7 | 400·5 | 300 2 | 412·5 | 312·5 | 425·5 | 325 5 | | |
| 62 | 380 9 | 278·8 | 391·1 | 289·6 | 402·0 | 301·0 | 413·6 | 313 0 | 426·0 | 325·8 | 439·4 | 339·3 | 453·7 | 353·7 |
| 63 | 393 9 | 291 0 | 404 4 | 302·2 | 415·7 | 314·1 | 427·7 | 326·6 | 440·5 | 339·9 | 454·3 | 354·1 | 469·2 | 369 1 |
| 64 | 407 9 | 303 9 | 418·8 | 315 7 | 430·5 | 328 1 | 442·9 | 341·2 | 456·2 | 355·1 | 470·5 | 369 9 | 485 9 | 385 6 |
| 65 | 423 1 | 317 9 | 434 0 | 330 2 | 446 5 | 343 2 | 459·4 | 356 9 | 473·2 | 371·4 | 488·1 | 386 9 | 504 0 | 403 3 |
| 66 | 439 7 | 333 0 | 451·4 | 345·9 | 464·0 | 359·4 | 477·4 | 373 8 | 491·7 | 389·0 | 507·1 | 405·2 | 523 7 | 422 4 |
| 67 | 457·7 | 349·3 | 469 9 | 362·8 | 483·0 | 377·0 | 496·9 | 392·1 | 511·9 | 398·8 | 527·9 | 425·0 | 545·1 | 443 1 |
| 68 | 477·4 | 366 9 | 490·1 | 381·1 | 503·7 | 396·1 | 518·3 | 411·9 | 533·9 | 428·7 | 550 6 | 446·5 | 568·6 | 465 5 |
| 69 | 499 0 | 386·2 | 512·3 | 401·1 | 526·6 | 416·9 | 541·8 | 433 6 | 558·1 | 451·2 | 575·6 | 470·0 | 594 4 | 489 9 |
| 70 | 522·9 | 407·3 | 536 8 | 423·1 | 551·7 | 429·7 | 567·7 | 457·3 | 584·8 | 475·9 | 603·1 | 495·7 | 622·8 | 516·7 |
| 71 | 549 3 | 430 6 | 564·0 | 447·2 | 579·6 | 464·8 | 596·4 | 483·3 | 614·3 | 503·0 | 633 6 | 523 9 | 654 3 | 546·2 |
| 72 | 578·7 | 456·3 | 594·2 | 473·9 | 610·7 | 492·5 | 628·3 | 512·2 | 647·2 | 533·1 | 667·5 | 555·2 | 689 3 | 578·8 |
| 73 | 611·6 | 484·9 | 628·0 | 503·7 | 645·4 | 523·4 | 664·1 | 544·4 | 684·1 | 566·7 | 705·5 | 590·1 | 728·5 | 615·2 |
| 74 | 648·8 | 517·0 | 666·1 | 537·0 | 684·6 | 558·1 | 704·4 | 580·5 | 725·6 | 604·0 | 748·3 | 629·1 | 772·8 | 655·9 |
| 75 | 690·9 | 553·3 | 709·4 | 574·7 | 729·1 | 597·3 | 756·2 | 621·1 | 772·7 | 646·4 | 796·9 | 673·3 | 823·0 | 701·9 |
| 76 | 739 2 | 594·6 | 758·9 | 617·6 | 780·0 | 641·9 | 802·6 | 667·5 | 826·7 | 694·7 | 852·6 | 723 6 | 880 5 | 754 3 |
| 77 | 795·0 | 642·2 | 816·2 | 667·0 | 838·9 | 693·2 | 863·1 | 720·9 | 889·1 | 750·2 | 916 9 | 781·4 | 946 9 | 814 6 |
| 78 | 860·1 | 697·5 | 883·1 | 724·5 | 907·6 | 752·9 | 933·9 | 783·0 | 961·9 | 814·9 | 992·1 | 848·8 | 1024 | 884 8 |
| 79 | 937·2 | 762·7 | 962·3 | 792·2 | 989·0 | 823·3 | 1018 | 856·2 | 1048 | 891·1 | 1081 | 928·1 | 1116 | 967 6 |
| 80 | 1030 | 840·8 | 1057 | 873·3 | 1087 | 907·6 | 1118 | 943·9 | 1152 | 982.3 | 1188 | 1023 | 1227 | 1067 |

| | 63° | | 64° | | 65° | | 66° | | 67° | | 68° | | 69° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 63 | 485·2 | 385·2 | | | | | | | | | | | | |
| 64 | 502·5 | 402.4 | 520·4 | 420·4 | | | | | | | | | | |
| 65 | 521·2 | 420·9 | 539·8 | 439·7 | 559·9 | 459·9 | | | | | | | | |
| 66 | 541·6 | 440·8 | 560·9 | 460·5 | 581·8 | 481·7 | 604·5 | 504·5 | | | | | | |
| 67 | 563·7 | 462·4 | 583·8 | 483·0 | 605·6 | 505·2 | 629·2 | 529·1 | 655·0 | 555·0 | | | | |
| 68 | 588·0 | 485·8 | 608·9 | 507·5 | 631·6 | 530·8 | 656·3 | 555·9 | 683·2 | 583·1 | 712·6 | 612·6 | | |
| 69 | 614·6 | 511·3 | 636·5 | 534·1 | 660·3 | 558·7 | 686·1 | 595·1 | 714·2 | 613·7 | 744·9 | 644·8 | 778·6 | 678·6 |
| 70 | 644·0 | 539·2 | 667·0 | 563·3 | 691·8 | 589·2 | 718·9 | 617·1 | 748·3 | 647·3 | 780·5 | 680·0 | 815·9 | 715·7 |
| 71 | 676·6 | 570·0 | 700·7 | 595·4 | 726·8 | 622·8 | 755·2 | 652·3 | 786·1 | 684·2 | 819·9 | 718 8 | 857·1 | 756 6 |
| 72 | 712·8 | 604·0 | 738·2 | 631·0 | 765·7 | 660·0 | 795·6 | 691·3 | 828·2 | 725·1 | 863·9 | 761·7 | 903·0 | 801·8 |
| 73 | 753·4 | 641·9 | 780·2 | 670·6 | 809·3 | 701·4 | 840·9 | 734·6 | 875·3 | 770·6 | 913·0 | 809·6 | 954·4 | 852·1 |
| 74 | 799·1 | 684·4 | 827·6 | 715·0 | 858·4 | 747·9 | 892·0 | 783·3 | 928·5 | 821·6 | 968·5 | 863·2 | 1002 | 908·5 |
| 75 | 851·0 | 732·5 | 881·4 | 765·2 | 914·2 | 800·4 | 949·9 | 838·2 | 988·8 | 879·2 | 1031 | 923·7 | 1078 | 972·2 |
| 76 | 910·5 | 787·2 | 942·9 | 822·3 | 978·1 | 860·1 | 1016 | 900·8 | 1058 | 944·9 | 1103 | 992·7 | 1153 | 1045 |
| 77 | 979·2 | 850·1 | 1014 | 888·1 | 1052 | 928·9 | 1093 | 972·9 | 1138 | 1020 | 1187 | 1072 | 1241 | 1128 |
| 78 | 1059 | 923·3 | 1097 | 964·6 | 1087 | 1009 | 1183 | 1057 | 1231 | 1108 | 1284 | 1164 | 1342 | 1226 |
| 79 | 1154 | 1010 | 1196 | 1055 | 1240 | 1103 | 1288 | 1155 | 1341 | 1212 | 1399 | 1273 | 1462 | 1340 |
| 80 | 1268 | 1113 | 1314 | 1163 | 1363 | 1216 | 1416 | 1274 | 1474 | 1336 | 1537 | 1404 | 1607 | 1477 |

| | 70° | | 71° | | 72° | | 73° | | 74° | | 75° | | 76° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | M | N | M | N | M | N | M | N | M | N | M | N | M | N |
| 70 | 854·9 | 754·9 | | | | | | | | | | | | |
| 71 | 898·1 | 797·9 | 943·5 | 843·5 | | | | | | | | | | |
| 72 | 946·2 | 845·6 | 994·0 | 893·8 | 1047 | 947·2 | | | | | | | | |
| 73 | 1000 | 898·6 | 1051 | 949·9 | 1107 | 1008 | 1170 | 1070 | | | | | | |
| 74 | 1061 | 958·1 | 1114 | 1013 | 1174 | 1073 | 1241 | 1141 | 1316 | 1216 | | | | |
| 75 | 1130 | 1025 | 1187 | 1084 | 1250 | 1149 | 1321 | 1221 | 1402 | 1301 | 1493 | 1394 | | |
| 76 | 1209 | 1102 | 1270 | 1165 | 1338 | 1234 | 1414 | 1312 | 1500 | 1399 | 1597 | 1497 | 1709 | 1609 |
| 77 | 1300 | 1190 | 1366 | 1258 | 1439 | 1333 | 1520 | 1417 | 1613 | 1511 | 1718 | 1617 | 1838 | 1737 |
| 78 | 1406 | 1293 | 1477 | 1366 | 1556 | 1448 | 1645 | 1539 | 1745 | 1641 | 1858 | 1756 | 1988 | 1887 |
| 79 | 1532 | 1413 | 1610 | 1494 | 1696 | 1583 | 1793 | 1683 | 1901 | 1794 | 2025 | 1920 | 2116 | 2063 |
| 80 | 1684 | 1558 | 1769 | 1647 | 1864 | 1745 | 1970 | 1856 | 2089 | 1978 | 2225 | 2117 | 2380 | 2275 |

## TABLE OF FACTORS.

| Deg. | $0^h$ | Fact. | Deg. | $1^h$ | Fact. | Deg. | $2^h$ | Fact. | Deg. | $3^h$ | Fact. | Deg. | $4^h$ | Fact. | Deg. | $5^h$ | Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | | | m | | | m | | | m | | | m | | | m | |
| 0° | 0 | 00·00 | 15° | 0 | 25·88 | 30° | 0 | 50·00 | 45° | 0 | 70·71 | 60° | 0 | 86·60 | 75° | 0 | 96·59 |
| 15′ | 1 | 00·44 | 15′ | 1 | 26 30 | 15′ | 1 | 50 38 | 15′ | 1 | 71·02 | 15′ | 1 | 86 82 | 15′ | 1 | 96·71 |
| 30 | 2 | 00·87 | 30 | 2 | 26 72 | 30 | 2 | 50·75 | 30 | 2 | 71·33 | 30 | 2 | 87·04 | 30 | 2 | 96·82 |
| 45 | 3 | 01·31 | 45 | 3 | 27·14 | 45 | 3 | 51·13 | 45 | 3 | 71·63 | 45 | 3 | 87·25 | 45 | 3 | 96·92 |
| 1° | 4 | 01·75 | 16° | 4 | 27 56 | 31° | 4 | 51·50 | 46° | 4 | 71·93 | 61° | 4 | 87·46 | 76° | 4 | 97·03 |
| 15′ | 5 | 02·18 | 15′ | 5 | 27·98 | 15′ | 5 | 51·88 | 15′ | 5 | 72·24 | 15′ | 5 | 87·67 | 15′ | 5 | 97·13 |
| 30 | 6 | 02·62 | 30 | 6 | 28·40 | 30 | 6 | 52·25 | 30 | 6 | 72·54 | 30 | 6 | 87·88 | 30 | 6 | 97·24 |
| 45 | 7 | 03·05 | 45 | 7 | 28·82 | 45 | 7 | 52·62 | 45 | 7 | 72·84 | 45 | 7 | 88·09 | 45 | 7 | 97·34 |
| 2° | 8 | 03·49 | 17° | 8 | 29 24 | 32° | 8 | 52·99 | 47° | 8 | 73·14 | 62° | 8 | 88·30 | 77° | 8 | 97·44 |
| 15′ | 9 | 03 93 | 15′ | 9 | 29 65 | 15′ | 9 | 53 36 | 15′ | 9 | 73·43 | 15′ | 9 | 88·50 | 15′ | 9 | 97·53 |
| 30 | 10 | 04·36 | 30 | 10 | 30 07 | 30 | 10 | 53·73 | 30 | 10 | 73·73 | 30 | 10 | 88·70 | 30 | 10 | 97·63 |
| 45 | 11 | 04·80 | 45 | 11 | 30·49 | 45 | 11 | 54·10 | 45 | 11 | 74·02 | 45 | 11 | 88·90 | 45 | 11 | 97·72 |
| 3° | 12 | 05·23 | 18° | 12 | 30 90 | 33° | 12 | 54 46 | 48° | 12 | 74·31 | 63° | 12 | 89 10 | 78° | 12 | 97·82 |
| 15′ | 13 | 05·67 | 15′ | 13 | 31·32 | 15′ | 13 | 54 83 | 15′ | 13 | 74 61 | 15′ | 13 | 89 30 | 15′ | 13 | 97·91 |
| 30 | 14 | 06·11 | 30 | 14 | 31·73 | 30 | 14 | 55·19 | 30 | 14 | 74·90 | 30 | 14 | 89·49 | 30 | 14 | 97·99 |
| 45 | 15 | 06 54 | 45 | 15 | 32·14 | 45 | 15 | 55 56 | 45 | 15 | 75·18 | 45 | 15 | 89 69 | 45 | 15 | 98·08 |
| 4° | 16 | 06·98 | 19° | 16 | 32 56 | 34° | 16 | 55 92 | 49° | 16 | 75·47 | 64° | 16 | 89 88 | 79° | 16 | 98·16 |
| 15′ | 17 | 07·41 | 15′ | 17 | 32·97 | 15′ | 17 | 56 28 | 15′ | 17 | 75·76 | 15′ | 17 | 90·07 | 15′ | 17 | 98·25 |
| 30 | 18 | 07·85 | 30 | 18 | 33·38 | 30 | 18 | 56 64 | 30 | 18 | 76·04 | 30 | 18 | 90·26 | 30 | 18 | 98·33 |
| 45 | 19 | 08·28 | 45 | 19 | 33 79 | 45 | 19 | 57·00 | 45 | 19 | 76·32 | 45 | 19 | 90·45 | 45 | 19 | 98·40 |
| 5° | 20 | 08·72 | 20° | 20 | 34·20 | 35° | 20 | 57·36 | 50° | 20 | 76 60 | 65° | 20 | 90 63 | 80° | 20 | 98·48 |
| 15′ | 21 | 09·15 | 15′ | 21 | 34 61 | 15′ | 21 | 57·72 | 15′ | 21 | 76·88 | 15′ | 21 | 90·81 | 15′ | 21 | 98·56 |
| 30 | 22 | 09·59 | 30 | 22 | 35 02 | 30 | 22 | 58 07 | 30 | 22 | 77·16 | 30 | 22 | 91·00 | 30 | 22 | 98·63 |
| 45 | 23 | 10·02 | 45 | 23 | 35·43 | 45 | 23 | 58·43 | 45 | 23 | 77·44 | 45 | 23 | 91·18 | 45 | 23 | 98·70 |
| 6° | 24 | 10·45 | 21° | 24 | 35 84 | 36° | 24 | 58·78 | 51° | 24 | 77·72 | 66° | 24 | 91·36 | 81° | 24 | 98·77 |
| 15′ | 25 | 10·89 | 15′ | 25 | 36·24 | 15′ | 25 | 59·13 | 15′ | 25 | 77·99 | 15′ | 25 | 91·53 | 15′ | 25 | 98·84 |
| 30 | 26 | 11·32 | 30 | 26 | 36 65 | 30 | 26 | 59·48 | 30 | 26 | 78·26 | 30 | 26 | 91·71 | 30 | 26 | 98·90 |
| 45 | 27 | 11·75 | 45 | 27 | 37·06 | 45 | 27 | 59 83 | 45 | 27 | 78·53 | 45 | 27 | 91·88 | 45 | 27 | 98·97 |
| 7° | 28 | 12·19 | 22° | 28 | 37·46 | 37° | 28 | 60·18 | 52° | 28 | 78·80 | 67° | 28 | 92·05 | 82° | 28 | 99·03 |
| 15′ | 29 | 12·62 | 15′ | 29 | 37·87 | 15′ | 29 | 60·53 | 15′ | 29 | 79·07 | 15′ | 29 | 92·22 | 15′ | 29 | 99·09 |
| 30 | 30 | 13·05 | 30 | 30 | 38·27 | 30 | 30 | 60·88 | 30 | 30 | 79·34 | 30 | 30 | 92·39 | 30 | 30 | 99·14 |
| 45 | 31 | 13·49 | 45 | 31 | 38·67 | 45 | 31 | 61·22 | 45 | 31 | 79 60 | 45 | 31 | 92·55 | 45 | 31 | 99·20 |
| 8° | 32 | 13·92 | 23° | 32 | 39·07 | 38° | 32 | 61·57 | 53° | 32 | 79·86 | 68° | 32 | 92·72 | 83° | 32 | 99·26 |
| 15′ | 33 | 14·35 | 15′ | 33 | 39·47 | 15′ | 33 | 61·91 | 15′ | 33 | 80·13 | 15′ | 33 | 92·88 | 15′ | 33 | 99·31 |
| 30 | 34 | 14·78 | 30 | 34 | 39 88 | 30 | 34 | 62·25 | 30 | 34 | 80·39 | 30 | 34 | 93·04 | 30 | 34 | 99·36 |
| 45 | 35 | 15·21 | 45 | 35 | 40·28 | 45 | 35 | 62·59 | 45 | 35 | 80·64 | 45 | 35 | 93·20 | 45 | 35 | 99·41 |
| 9° | 36 | 15·64 | 24° | 36 | 40·67 | 39° | 36 | 62·93 | 54° | 36 | 80·90 | 69° | 36 | 93·36 | 84° | 36 | 99·45 |
| 15′ | 37 | 16·07 | 15′ | 37 | 41·07 | 15′ | 37 | 63·27 | 15′ | 37 | 81·16 | 15′ | 37 | 93·51 | 15′ | 37 | 99·50 |
| 30 | 38 | 16·51 | 30 | 38 | 41·47 | 30 | 38 | 63·61 | 30 | 38 | 81·41 | 30 | 38 | 93·67 | 30 | 38 | 99·54 |
| 45 | 39 | 16·94 | 45 | 39 | 41·87 | 45 | 39 | 63·94 | 45 | 39 | 81·66 | 45 | 39 | 93·82 | 45 | 39 | 99·58 |
| 10° | 40 | 17·37 | 25° | 40 | 42·26 | 40° | 40 | 64·28 | 55° | 40 | 81·92 | 70° | 40 | 93·97 | 85° | 40 | 99·62 |
| 15′ | 41 | 17·79 | 15′ | 41 | 42·66 | 15′ | 41 | 64·61 | 15′ | 41 | 82·17 | 15′ | 41 | 94·12 | 15′ | 41 | 99·66 |
| 30 | 42 | 18·22 | 30 | 42 | 43·05 | 30 | 42 | 64·95 | 30 | 42 | 82·41 | 30 | 42 | 94·26 | 30 | 42 | 99·69 |
| 45 | 43 | 18·65 | 45 | 43 | 43·45 | 45 | 43 | 65·28 | 45 | 43 | 82·66 | 45 | 43 | 94·41 | 45 | 43 | 99·73 |
| 11° | 44 | 19·08 | 26° | 44 | 43·84 | 41° | 44 | 65·61 | 56° | 44 | 82·90 | 71° | 44 | 94·55 | 86° | 44 | 99·76 |
| 15′ | 45 | 19·51 | 15′ | 45 | 44·23 | 15′ | 45 | 65·94 | 15′ | 45 | 83·15 | 15′ | 45 | 94·69 | 15′ | 45 | 99·79 |
| 30 | 46 | 19·94 | 30 | 46 | 44·62 | 30 | 46 | 66·26 | 30 | 46 | 83·39 | 30 | 46 | 94·83 | 30 | 46 | 99·81 |
| 45 | 47 | 20·36 | 45 | 47 | 45·01 | 45 | 47 | 66·59 | 45 | 47 | 83·63 | 45 | 47 | 94·97 | 45 | 47 | 99·84 |
| 12° | 48 | 20·79 | 27° | 48 | 45·40 | 42° | 48 | 66·91 | 57° | 48 | 83·87 | 72° | 48 | 95·11 | 87° | 48 | 99·86 |
| 15′ | 49 | 21·22 | 15′ | 49 | 45·79 | 15′ | 49 | 67·24 | 15′ | 49 | 84·10 | 15′ | 49 | 95·24 | 15′ | 49 | 99·89 |
| 30 | 50 | 21·64 | 30 | 50 | 46·18 | 30 | 50 | 67·56 | 30 | 50 | 84·34 | 30 | 50 | 95·37 | 30 | 50 | 99·91 |
| 45 | 51 | 22·07 | 45 | 51 | 46·56 | 45 | 51 | 67·88 | 45 | 51 | 84·57 | 45 | 51 | 95·50 | 45 | 51 | 99·92 |
| 13° | 52 | 22·50 | 28° | 52 | 46·95 | 43° | 52 | 68·20 | 58° | 52 | 84·81 | 73° | 52 | 95·63 | 88° | 52 | 99·94 |
| 15′ | 53 | 22·92 | 15′ | 53 | 47·33 | 15′ | 53 | 68·52 | 15′ | 53 | 85·04 | 15′ | 53 | 95·76 | 15′ | 53 | 99·95 |
| 30 | 54 | 23·35 | 30 | 54 | 47·71 | 30 | 54 | 68·84 | 30 | 54 | 85·26 | 30 | 54 | 95·88 | 30 | 54 | 99·97 |
| 45 | 55 | 23·77 | 45 | 55 | 48·10 | 45 | 55 | 69·15 | 45 | 55 | 85·49 | 45 | 55 | 96·01 | 45 | 55 | 99·98 |
| 14° | 56 | 24·19 | 29° | 56 | 48·48 | 44° | 56 | 69·47 | 59° | 56 | 85·72 | 74° | 56 | 96·13 | 89° | 56 | 99·99 |
| 15′ | 57 | 24·62 | 15′ | 57 | 48·86 | 15′ | 57 | 69·78 | 15′ | 57 | 85·94 | 15′ | 57 | 96·25 | 15′ | 57 | 99·99 |
| 30 | 58 | 25·04 | 30 | 58 | 49·24 | 30 | 58 | 70·09 | 30 | 58 | 86·16 | 30 | 58 | 96·36 | 30 | 58 | 100·0 |
| 45 | 59 | 25·46 | 45 | 59 | 49·62 | 45 | 59 | 70·40 | 45 | 59 | 86·38 | 45 | 59 | 96·48 | 45 | 59 | 100·0 |
| 15° | 60 | 25·88 | 30° | 60 | 50·00 | 45° | 60 | 70·71 | 60° | 60 | 86·60 | 75° | 60 | 96·59 | 90° | 60 | 100·0 |

## LOGARITHMS OF NUMBERS.

| Natural Numbers. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Proportional Parts. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0000 | 0043 | 0086 | 0128 | 0170 | 0212 | 0253 | 0294 | 0334 | 0374 | 4 | 8 | 12 | 17 | 21 | 25 | 29 | 33 | 37 |
| 11 | 0414 | 0453 | 0492 | 0531 | 0569 | 0607 | 0645 | 0682 | 0719 | 0755 | 4 | 8 | 11 | 15 | 19 | 23 | 26 | 30 | 34 |
| 12 | 0792 | 0828 | 0864 | 0899 | 0934 | 0969 | 1004 | 1038 | 1072 | 1106 | 3 | 7 | 10 | 14 | 17 | 21 | 24 | 28 | 31 |
| 13 | 1139 | 1173 | 1206 | 1239 | 1271 | 1303 | 1335 | 1367 | 1399 | 1430 | 3 | 6 | 10 | 13 | 16 | 19 | 23 | 26 | 29 |
| 14 | 1461 | 1492 | 1523 | 1553 | 1584 | 1614 | 1644 | 1673 | 1703 | 1732 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 15 | 1761 | 1790 | 1818 | 1847 | 1875 | 1903 | 1931 | 1959 | 1987 | 2014 | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 |
| 16 | 2041 | 2068 | 2095 | 2122 | 2148 | 2175 | 2201 | 2227 | 2253 | 2279 | 3 | 5 | 8 | 11 | 13 | 16 | 18 | 21 | 24 |
| 17 | 2304 | 2330 | 2355 | 2380 | 2405 | 2430 | 2455 | 2480 | 2504 | 2529 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 |
| 18 | 2553 | 2577 | 2601 | 2625 | 2648 | 2672 | 2695 | 2718 | 2742 | 2765 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 19 | 21 |
| 19 | 2788 | 2810 | 2833 | 2856 | 2878 | 2900 | 2923 | 2945 | 2967 | 2989 | 2 | 4 | 7 | 9 | 11 | 13 | 16 | 18 | 20 |
| 20 | 3010 | 3032 | 3054 | 3075 | 3096 | 3118 | 3139 | 3160 | 3181 | 3201 | 2 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 |
| 21 | 3222 | 3243 | 3263 | 3284 | 3304 | 3324 | 3345 | 3365 | 3385 | 3404 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 22 | 3424 | 3444 | 3464 | 3483 | 3502 | 3522 | 3541 | 3560 | 3579 | 3598 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 | 17 |
| 23 | 3617 | 3636 | 3655 | 3674 | 3692 | 3711 | 3729 | 3747 | 3766 | 3784 | 2 | 4 | 6 | 7 | 9 | 11 | 13 | 15 | 17 |
| 24 | 3802 | 3820 | 3838 | 3856 | 3874 | 3892 | 3909 | 3927 | 3945 | 3962 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 |
| 25 | 3979 | 3997 | 4014 | 4031 | 4048 | 4065 | 4082 | 4099 | 4116 | 4133 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 15 |
| 26 | 4150 | 4166 | 4183 | 4200 | 4216 | 4232 | 4249 | 4265 | 4281 | 4298 | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 |
| 27 | 4314 | 4330 | 4346 | 4362 | 4378 | 4393 | 4409 | 4425 | 4440 | 4456 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 13 | 14 |
| 28 | 4472 | 4487 | 4502 | 4518 | 4533 | 4548 | 4564 | 4579 | 4594 | 4609 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 |
| 29 | 4624 | 4639 | 4654 | 4669 | 4683 | 4698 | 4713 | 4728 | 4742 | 4757 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 |
| 30 | 4771 | 4786 | 4800 | 4814 | 4829 | 4843 | 4857 | 4871 | 4886 | 4900 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 |
| 31 | 4914 | 4928 | 4942 | 4955 | 4969 | 4983 | 4997 | 5011 | 5024 | 5038 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 |
| 32 | 5051 | 5065 | 5079 | 5092 | 5105 | 5119 | 5132 | 5145 | 5159 | 5172 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 |
| 33 | 5185 | 5198 | 5211 | 5224 | 5237 | 5250 | 5263 | 5276 | 5289 | 5302 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 12 |
| 34 | 5315 | 5328 | 5340 | 5353 | 5366 | 5378 | 5391 | 5403 | 5416 | 5428 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 35 | 5441 | 5453 | 5465 | 5478 | 5490 | 5502 | 5514 | 5527 | 5539 | 5551 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 |
| 36 | 5563 | 5575 | 5587 | 5599 | 5611 | 5623 | 5635 | 5647 | 5658 | 5670 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 37 | 5682 | 5694 | 5705 | 5717 | 5729 | 5740 | 5752 | 5763 | 5775 | 5786 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 38 | 5798 | 5809 | 5821 | 5832 | 5843 | 5855 | 5866 | 5877 | 5888 | 5899 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 39 | 5911 | 5922 | 5933 | 5944 | 5955 | 5966 | 5977 | 5988 | 5999 | 6010 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| 40 | 6021 | 6031 | 6042 | 6053 | 6064 | 6075 | 6085 | 6096 | 6107 | 6117 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
| 41 | 6128 | 6138 | 6149 | 6160 | 6170 | 6180 | 6191 | 6201 | 6212 | 6222 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 42 | 6232 | 6243 | 6253 | 6263 | 6274 | 6284 | 6294 | 6304 | 6314 | 6325 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 43 | 6335 | 6345 | 6355 | 6365 | 6375 | 6385 | 6395 | 6405 | 6415 | 6425 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 44 | 6435 | 6444 | 6454 | 6464 | 6474 | 6484 | 6493 | 6503 | 6513 | 6522 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 45 | 6532 | 6542 | 6551 | 6561 | 6571 | 6580 | 6590 | 6599 | 6609 | 6618 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 46 | 6628 | 6637 | 6646 | 6656 | 6665 | 6675 | 6684 | 6693 | 6702 | 6712 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 |
| 47 | 6721 | 6730 | 6739 | 6749 | 6758 | 6767 | 6776 | 6785 | 6794 | 6803 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 48 | 6812 | 6821 | 6830 | 6839 | 6848 | 6857 | 6866 | 6875 | 6884 | 6893 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 49 | 6902 | 6911 | 6920 | 6928 | 6937 | 6946 | 6955 | 6964 | 6972 | 6981 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| 50 | 6990 | 6998 | 7007 | 7016 | 7024 | 7033 | 7042 | 7050 | 7059 | 7067 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 51 | 7076 | 7084 | 7093 | 7101 | 7110 | 7118 | 7126 | 7135 | 7143 | 7152 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
| 52 | 7160 | 7168 | 7177 | 7185 | 7193 | 7202 | 7210 | 7218 | 7226 | 7235 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |
| 53 | 7243 | 7251 | 7259 | 7267 | 7275 | 7284 | 7292 | 7300 | 7308 | 7316 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 54 | 7324 | 7332 | 7340 | 7348 | 7356 | 7364 | 7372 | 7380 | 7388 | 7396 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 55 | 7404 | 7412 | 7419 | 7427 | 7435 | 7443 | 7451 | 7459 | 7466 | 7474 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 56 | 7482 | 7490 | 7497 | 7505 | 7513 | 7520 | 7528 | 7536 | 7543 | 7551 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 57 | 7559 | 7566 | 7574 | 7582 | 7589 | 7597 | 7604 | 7612 | 7619 | 7627 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 |
| 58 | 7634 | 7642 | 7649 | 7657 | 7664 | 7672 | 7679 | 7686 | 7694 | 7701 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 59 | 7709 | 7716 | 7723 | 7731 | 7738 | 7745 | 7752 | 7760 | 7767 | 7774 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 60 | 7782 | 7789 | 7796 | 7803 | 7810 | 7818 | 7825 | 7832 | 7839 | 7846 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 61 | 7853 | 7860 | 7868 | 7875 | 7882 | 7889 | 7896 | 7903 | 7910 | 7917 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 |
| 62 | 7924 | 7931 | 7938 | 7945 | 7952 | 7959 | 7966 | 7973 | 7980 | 7987 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 |
| 63 | 7993 | 8000 | 8007 | 8014 | 8021 | 8028 | 8035 | 8041 | 8048 | 8055 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 64 | 8062 | 8069 | 8075 | 8082 | 8089 | 8096 | 8102 | 8109 | 8116 | 8122 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |

## LOGARITHMS OF NUMBERS.

| Natural Numbers. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Proportional Parts. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 8129 | 8136 | 8142 | 8149 | 8156 | 8162 | 8169 | 8176 | 8182 | 8189 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 66 | 8195 | 8202 | 8209 | 8215 | 8222 | 8228 | 8235 | 8241 | 8248 | 8254 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 67 | 8261 | 8267 | 8274 | 8280 | 8287 | 8293 | 8299 | 8306 | 8312 | 8319 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 68 | 8325 | 8331 | 8338 | 8344 | 8351 | 8357 | 8363 | 8370 | 8376 | 8382 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 |
| 69 | 8388 | 8395 | 8401 | 8407 | 8414 | 8420 | 8426 | 8432 | 8439 | 8445 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 70 | 8451 | 8457 | 8463 | 8470 | 8476 | 8482 | 8488 | 8494 | 8500 | 8506 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 71 | 8513 | 8519 | 8525 | 8531 | 8537 | 8543 | 8549 | 8555 | 8561 | 8567 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 72 | 8573 | 8579 | 8585 | 8591 | 8597 | 8603 | 8609 | 8615 | 8621 | 8627 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 73 | 8633 | 8639 | 8645 | 8651 | 8657 | 8663 | 8669 | 8675 | 8681 | 8686 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 74 | 8692 | 8698 | 8704 | 8710 | 8716 | 8722 | 8727 | 8733 | 8739 | 8745 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 75 | 8751 | 8756 | 8762 | 8768 | 8774 | 8779 | 8785 | 8791 | 8797 | 8802 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 76 | 8808 | 8814 | 8820 | 8825 | 8831 | 8837 | 8842 | 8848 | 8854 | 8859 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 77 | 8865 | 8871 | 8876 | 8882 | 8887 | 8893 | 8899 | 8904 | 8910 | 8915 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 78 | 8921 | 8927 | 8932 | 8938 | 8943 | 8949 | 8954 | 8960 | 8965 | 8971 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 79 | 8976 | 8982 | 8987 | 8993 | 8998 | 9004 | 9009 | 9015 | 9020 | 9025 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 80 | 9031 | 9036 | 9042 | 9047 | 9053 | 9058 | 9063 | 9069 | 9074 | 9079 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 81 | 9085 | 9090 | 9096 | 9101 | 9106 | 9112 | 9117 | 9122 | 9128 | 9133 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 82 | 9138 | 9143 | 9149 | 9154 | 9159 | 9165 | 9170 | 9175 | 9180 | 9186 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 83 | 9191 | 9196 | 9201 | 9206 | 9212 | 9217 | 9222 | 9227 | 9232 | 9238 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 84 | 9243 | 9248 | 9253 | 9258 | 9263 | 9269 | 9274 | 9279 | 9284 | 9289 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 85 | 9294 | 9299 | 9304 | 9309 | 9315 | 9320 | 9325 | 9330 | 9335 | 9340 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 86 | 9345 | 9350 | 9355 | 9360 | 9365 | 9370 | 9375 | 9380 | 9385 | 9390 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 87 | 9395 | 9400 | 9405 | 9410 | 9415 | 9420 | 9425 | 9430 | 9435 | 9440 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 88 | 9445 | 9450 | 9455 | 9460 | 9465 | 9469 | 9474 | 9479 | 9484 | 9489 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 89 | 9494 | 9499 | 9504 | 9509 | 9513 | 9518 | 9523 | 9528 | 9533 | 9538 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 90 | 9542 | 9547 | 9552 | 9557 | 9562 | 9566 | 9571 | 9576 | 9581 | 9586 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 91 | 9590 | 9595 | 9600 | 9605 | 9609 | 9614 | 9619 | 9624 | 9628 | 9633 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 92 | 9638 | 9643 | 9647 | 9652 | 9657 | 9661 | 9666 | 9671 | 9675 | 9680 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 93 | 9685 | 9689 | 9694 | 9699 | 9703 | 9708 | 9713 | 9717 | 9722 | 9727 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 94 | 9731 | 9736 | 9741 | 9745 | 9750 | 9754 | 9759 | 9763 | 9768 | 9773 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 95 | 9777 | 9782 | 9786 | 9791 | 9795 | 9800 | 9805 | 9809 | 9814 | 9818 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 96 | 9823 | 9827 | 9832 | 9836 | 9841 | 9845 | 9850 | 9854 | 9859 | 9863 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 97 | 9868 | 9872 | 9877 | 9881 | 9886 | 9890 | 9894 | 9899 | 9903 | 9908 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 98 | 9912 | 9917 | 9921 | 9926 | 9930 | 9934 | 9939 | 9943 | 9948 | 9952 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 99 | 9956 | 9961 | 9965 | 9969 | 9974 | 9978 | 9983 | 9987 | 9991 | 9996 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |

## FOR COMPUTING THE MOON'S *SECOND* CORRECTION OF DISTANCE.

| ☽'s Corr. of Alt. or Dist. | Apparent Distance. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13° | 14° | 15° | 16° | 17° | 18° | 20° | 23° | 26° | 30° | 34° | 38° | 44° | 50° | 60° | 70° | 80° | 90° |
| | | | | | | | | | *add* | | | | | | | | | |
| ′ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 11 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 12 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 13 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 |
| 14 | 7 | 7 | 6 | 6 | 6 | 5 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 0 | 0 |
| 15 | 9 | 8 | 7 | 7 | 6 | 6 | 5 | 5 | 4 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 0 | 0 |
| 16 | 10 | 9 | 8 | 8 | 7 | 7 | 6 | 5 | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 0 | 0 |
| 17 | 11 | 10 | 9 | 9 | 8 | 8 | 7 | 6 | 5 | 4 | 4 | 3 | 3 | 2 | 1 | 1 | 0 | 0 |
| 18 | 12 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 6 | 5 | 4 | 4 | 3 | 2 | 2 | 1 | 0 | 0 |
| 19 | 14 | 13 | 12 | 11 | 10 | 10 | 9 | 7 | 6 | 5 | 5 | 4 | 3 | 3 | 2 | 1 | 1 | 0 |
| 20 | 15 | 14 | 13 | 12 | 11 | 11 | 10 | 8 | 7 | 6 | 5 | 4 | 4 | 3 | 2 | 1 | 1 | 0 |
| 21 | 17 | 15 | 14 | 13 | 13 | 12 | 11 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 0 |
| 22 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 10 | 9 | 7 | 6 | 5 | 4 | 4 | 2 | 2 | 1 | 0 |
| 23 | 20 | 19 | 17 | 16 | 15 | 14 | 13 | 11 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 24 | 22 | 20 | 19 | 18 | 16 | 15 | 14 | 12 | 10 | 9 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 25 | 24 | 22 | 20 | 19 | 18 | 17 | 15 | 13 | 11 | 9 | 8 | 7 | 6 | 5 | 3 | 2 | 1 | 0 |
| 26 | 26 | 24 | 22 | 21 | 19 | 18 | 16 | 14 | 12 | 10 | 9 | 8 | 6 | 5 | 3 | 2 | 1 | 0 |
| 27 | 28 | 26 | 24 | 22 | 21 | 20 | 17 | 15 | 13 | 11 | 9 | 8 | 7 | 5 | 4 | 2 | 1 | 0 |
| 28 | 30 | 27 | 26 | 24 | 22 | 21 | 19 | 16 | 14 | 12 | 10 | 9 | 7 | 6 | 4 | 2 | 1 | 0 |
| 29 | 32 | 29 | 27 | 26 | 24 | 23 | 20 | 17 | 15 | 13 | 11 | 9 | 8 | 6 | 4 | 3 | 1 | 0 |
| 30 | 34 | 31 | 29 | 27 | 26 | 24 | 22 | 19 | 16 | 14 | 12 | 10 | 8 | 7 | 5 | 3 | 1 | 0 |
| 31 | 36 | 34 | 31 | 29 | 27 | 26 | 23 | 20 | 17 | 15 | 12 | 11 | 9 | 7 | 5 | 3 | 1 | 0 |
| 32 | 39 | 36 | 33 | 31 | 29 | 27 | 25 | 21 | 18 | 15 | 13 | 11 | 9 | 7 | 5 | 3 | 2 | 0 |
| 33 | 41 | 38 | 35 | 33 | 31 | 29 | 26 | 22 | 19 | 16 | 14 | 12 | 10 | 8 | 5 | 3 | 2 | 0 |
| 34 | 44 | 40 | 38 | 35 | 33 | 31 | 28 | 24 | 21 | 17 | 15 | 13 | 10 | 8 | 6 | 4 | 2 | 0 |
| 35 | 46 | 43 | 40 | 37 | 35 | 33 | 29 | 25 | 22 | 19 | 16 | 14 | 11 | 9 | 6 | 4 | 2 | 0 |
| 36 | 49 | 45 | 42 | 39 | 37 | 35 | 31 | 27 | 23 | 20 | 17 | 14 | 12 | 9 | 7 | 4 | 2 | 0 |
| 37 | 52 | 48 | 45 | 42 | 39 | 37 | 33 | 28 | 24 | 21 | 18 | 15 | 12 | 10 | 7 | 4 | 2 | 0 |
| 38 | 55 | 51 | 47 | 44 | 41 | 39 | 35 | 30 | 26 | 22 | 19 | 16 | 13 | 11 | 7 | 5 | 2 | 0 |
| 39 | 57 | 53 | 50 | 46 | 43 | 41 | 36 | 31 | 27 | 23 | 20 | 17 | 14 | 11 | 8 | 5 | 2 | 0 |
| 40 | 60 | 56 | 52 | 49 | 46 | 43 | 38 | 33 | 29 | 24 | 21 | 18 | 14 | 12 | 8 | 5 | 2 | 0 |
| 41 | 63 | 59 | 55 | 51 | 48 | 45 | 40 | 35 | 30 | 25 | 22 | 19 | 15 | 12 | 8 | 5 | 3 | 0 |
| 42 | 67 | 62 | 57 | 54 | 50 | 47 | 42 | 36 | 32 | 27 | 23 | 20 | 16 | 13 | 9 | 6 | 3 | 0 |
| 43 | 70 | 65 | 60 | 56 | 53 | 50 | 44 | 38 | 33 | 28 | 24 | 21 | 17 | 14 | 9 | 6 | 3 | 0 |
| 44 | 73 | 68 | 63 | 59 | 55 | 52 | 46 | 40 | 35 | 29 | 25 | 22 | 17 | 14 | 10 | 6 | 3 | 0 |
| 45 | 76 | 71 | 66 | 62 | 58 | 54 | 49 | 42 | 36 | 31 | 26 | 23 | 18 | 15 | 10 | 6 | 3 | 0 |
| 46 | 80 | 74 | 69 | 64 | 60 | 57 | 51 | 43 | 38 | 32 | 27 | 24 | 19 | 15 | 11 | 7 | 3 | 0 |
| 47 | 83 | 77 | 72 | 67 | 63 | 59 | 53 | 45 | 40 | 33 | 29 | 25 | 20 | 16 | 11 | 7 | 3 | 0 |
| 48 | 87 | 81 | 75 | 70 | 66 | 62 | 55 | 47 | 41 | 35 | 30 | 26 | 21 | 17 | 12 | 7 | 4 | 0 |
| 49 | 91 | 84 | 78 | 73 | 68 | 64 | 58 | 49 | 43 | 36 | 31 | 27 | 22 | 18 | 12 | 8 | 4 | 0 |
| 50 | 94 | 87 | 81 | 76 | 71 | 67 | 60 | 51 | 45 | 38 | 32 | 28 | 23 | 18 | 13 | 8 | 4 | 0 |
| 51 | 98 | 91 | 85 | 79 | 74 | 70 | 62 | 53 | 47 | 39 | 34 | 29 | 24 | 19 | 13 | 8 | 4 | 0 |
| 52 | 102 | 95 | 88 | 82 | 77 | 73 | 65 | 56 | 48 | 41 | 35 | 30 | 24 | 20 | 14 | 9 | 4 | 0 |
| 53 | 106 | 98 | 91 | 85 | 80 | 75 | 67 | 58 | 50 | 42 | 36 | 31 | 25 | 21 | 14 | 9 | 4 | 0 |
| 54 | 110 | 102 | 95 | 89 | 83 | 78 | 70 | 60 | 52 | 44 | 38 | 33 | 26 | 21 | 15 | 9 | 4 | 0 |
| 55 | 114 | 106 | 98 | 92 | 86 | 81 | 72 | 62 | 54 | 46 | 39 | 34 | 27 | 22 | 15 | 10 | 5 | 0 |
| 56 | 118 | 110 | 102 | 95 | 89 | 84 | 75 | 64 | 56 | 47 | 41 | 35 | 28 | 23 | 16 | 10 | 5 | 0 |
| 57 | 123 | 114 | 106 | 99 | 93 | 87 | 78 | 67 | 58 | 49 | 42 | 36 | 29 | 24 | 16 | 10 | 5 | 0 |
| 58 | 127 | 118 | 109 | 102 | 96 | 90 | 81 | 69 | 60 | 51 | 44 | 38 | 30 | 25 | 17 | 11 | 5 | 0 |
| 59 | 131 | 122 | 113 | 106 | 99 | 93 | 83 | 72 | 62 | 53 | 45 | 39 | 31 | 25 | 18 | 11 | 5 | 0 |
| 60 | 136 | 126 | 117 | 109 | 103 | 97 | 86 | 74 | 64 | 54 | 47 | 40 | 33 | 26 | 18 | 11 | 6 | 0 |
| | | | | | | | | | | | | | | *sub.* | *sub.* | *sub.* | *sub.* | *sub.* |
| | | | | | | | | | | | | | | 130° | 120° | 110° | 100° | 90° |

## CORRECTION OF MOON'S PARALLAX.

| Lat. | Horizontal Parallax. | | | | |
|---|---|---|---|---|---|
| | 53′ | 55′ | 57′ | 59′ | 61′ |
| | ″ | ″ | ″ | ″ | ″ |
| 0° | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| 2 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| 4 | 0·1 | 0·1 | 0·1 | 0·1 | 0·1 |
| 6 | 0·1 | 0·1 | 0·1 | 0·1 | 0·1 |
| 8 | 0·2 | 0·2 | 0·2 | 0·2 | 0·2 |
| 10 | 0·3 | 0·3 | 0·3 | 0·4 | 0·4 |
| 12 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 |
| 14 | 0·6 | 0·6 | 0·7 | 0·7 | 0·7 |
| 16 | 0·8 | 0·8 | 0·9 | 0·9 | 0·9 |
| 18 | 1·0 | 1·0 | 1·1 | 1·1 | 1·1 |
| 20 | 1·2 | 1·3 | 1·3 | 1·4 | 1·4 |
| 21 | 1·3 | 1·4 | 1·4 | 1·5 | 1·5 |
| 22 | 1·5 | 1·5 | 1·6 | 1·6 | 1·7 |
| 23 | 1·6 | 1·7 | 1·7 | 1·8 | 1·8 |
| 24 | 1·7 | 1·8 | 1·8 | 1·9 | 2·0 |
| 25 | 1·9 | 1·9 | 2·0 | 2·1 | 2·1 |
| 26 | 2·0 | 2·1 | 2·2 | 2·2 | 2·3 |
| 27 | 2·1 | 2·2 | 2·3 | 2·4 | 2·5 |
| 28 | 2·3 | 2·4 | 2·5 | 2·6 | 2·6 |
| 29 | 2·4 | 2·5 | 2·6 | 2·7 | 2·8 |
| 30 | 2·6 | 2·7 | 2·8 | 2·9 | 3·0 |
| 31 | 2·8 | 2·9 | 3.0 | 3·1 | 3·2 |
| 32 | 2·9 | 3·0 | 3·1 | 3·3 | 3·4 |
| 33 | 3·1 | 3·2 | 3·3 | 3·4 | 3·6 |
| 34 | 3·3 | 3·4 | 3·5 | 3·6 | 3·8 |
| 35 | 3·4 | 3·6 | 3·7 | 3·8 | 3·9 |
| 36 | 3·6 | 3·7 | 3·9 | 4·0 | 4·1 |
| 37 | 3·8 | 3·9 | 4·1 | 4·2 | 4·3 |
| 38 | 4·0 | 4·1 | 4·3 | 4·4 | 4·6 |
| 39 | 4·1 | 4·3 | 4·4 | 4·6 | 4·8 |
| 40 | 4·3 | 4·5 | 4·6 | 4·8 | 5·0 |
| 41 | 4·5 | 4·7 | 4·8 | 5·0 | 5·2 |
| 42 | 4·7 | 4·8 | 5·0 | 5·2 | 5·4 |
| 43 | 4·9 | 5·0 | 5·2 | 5·4 | 5·6 |
| 44 | 5·0 | 5·2 | 5·4 | 5·6 | 5·8 |
| 45 | 5·2 | 5·4 | 5·6 | 5·8 | 6·0 |
| 46 | 5·4 | 5·6 | 5·8 | 6·0 | 6·2 |
| 47 | 5·6 | 5·8 | 6·0 | 6·2 | 6·4 |
| 48 | 5 8 | 6·0 | 6·2 | 6·4 | 6·6 |
| 49 | 5·9 | 6·2 | 6·4 | 6·6 | 6·8 |
| 50 | 6·1 | 6·4 | 6·6 | 6·8 | 7·1 |
| 52 | 6 5 | 6·7 | 7·0 | 7·2 | 7·5 |
| 54 | 6·8 | 7·1 | 7·4 | 7·6 | 7·9 |
| 56 | 7·2 | 7·4 | 7·7 | 8·0 | 8·3 |
| 58 | 7·5 | 7·8 | 8·1 | 8·4 | 8·6 |
| 60 | 7·8 | 8·1 | 8·4 | 8·7 | 9·0 |
| 62 | 8·1 | 8·5 | 8·8 | 9·1 | 9·4 |
| 64 | 8·4 | 8·8 | 9·1 | 9·4 | 9·7 |
| 66 | 8·7 | 9·1 | 9·4 | 9·7 | 10·0 |
| 68 | 9·0 | 9·3 | 9·7 | 10·0 | 10·3 |
| 70 | 9·2 | 9·6 | 9·9 | 10·3 | 10·6 |
| 72 | 9·5 | 9·8 | 10·2 | 10·5 | 10·9 |
| 74 | 9·7 | 10·0 | 10·4 | 10·8 | 11·1 |
| 76 | 9·8 | 10·2 | 10·6 | 11·0 | 11·3 |
| 78 | 10·0 | 10·4 | 10·8 | 11·1 | 11·5 |
| 80 | 10·1 | 10·5 | 10·9 | 11·3 | 11·7 |

## LOG. S. FOR SPHEROIDAL CORRECTION.

| Lat. | Horizontal Parallax. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 53′ | 54′ | 55′ | 56′ | 57′ | 58′ | 59′ | 60′ | 61′ |
| 0° | —Inf. | | | | | | | | |
| 1 | 9·560 | 9·568 | 9·576 | 9·584 | 9·592 | 9·599 | 9·607 | 9·614 | 9·621 |
| 2 | 9·861 | 9·869 | 9·877 | 9·885 | 9·893 | 9·900 | 9·908 | 9·915 | 9 922 |
| 3 | 0·037 | 0·045 | 0·053 | 0·061 | 0·069 | 0·076 | 0·084 | 0·091 | 0·098 |
| 4 | 0·162 | 0·170 | 0·178 | 0·186 | 0·194 | 0·201 | 0·209 | 0·216 | 0·223 |
| 5 | 0·259 | 0·267 | 0·275 | 0·283 | 0·290 | 0·298 | 0·305 | 0·313 | 0·320 |
| 6 | 0·338 | 0·346 | 0·354 | 0·362 | 0·369 | 0·377 | 0·384 | 0·392 | 0·399 |
| 7 | 0·404 | 0·412 | 0·420 | 0·428 | 0·436 | 0·444 | 0·451 | 0·458 | 0·465 |
| 8 | 0·462 | 0·470 | 0·478 | 0·486 | 0·494 | 0·501 | 0·509 | 0·516 | 0·523 |
| 9 | 0·513 | 0·521 | 0·529 | 0·537 | 0·544 | 0·552 | 0·559 | 0·567 | 0·574 |
| 10 | 0·558 | 0·566 | 0·574 | 0·582 | 0·590 | 0·597 | 0·605 | 0·612 | 0 619 |
| 11 | 0·599 | 0·607 | 0·615 | 0·623 | 0·631 | 0·638 | 0·646 | 0·653 | 0·660 |
| 12 | 0·636 | 0·645 | 0·652 | 0·660 | 0·668 | 0·676 | 0·683 | 0·690 | 0·697 |
| 13 | 0·671 | 0·679 | 0·687 | 0·695 | 0·702 | 0·710 | 0·717 | 0·724 | 0·732 |
| 14 | 0·702 | 0·710 | 0·718 | 0·726 | 0·734 | 0·741 | 0·749 | 0·756 | 0·763 |
| 15 | 0·732 | 0·740 | 0·748 | 0·755 | 0·763 | 0·771 | 0·778 | 0·785 | 0·793 |
| 16 | 0·759 | 0·767 | 0·775 | 0·783 | 0·790 | 0·798 | 0·805 | 0·813 | 0·820 |
| 17 | 0·785 | 0·793 | 0·801 | 0·808 | 0·816 | 0·824 | 0·831 | 0·838 | 0·846 |
| 18 | 0·809 | 0·817 | 0·825 | 0·832 | 0·840 | 0·848 | 0·855 | 0·862 | 0·870 |
| 19 | 0·831 | 0·839 | 0·847 | 0·855 | 0·863 | 0·870 | 0·878 | 0·885 | 0·892 |
| 20 | 0·853 | 0·861 | 0·869 | 0·877 | 0·844 | 0·892 | 0·899 | 0·907 | 0·914 |
| 21 | 0·873 | 0·881 | 0·889 | 0·897 | 0·905 | 0·912 | 0·920 | 0·927 | 0·934 |
| 22 | 0·892 | 0·900 | 0·908 | 0·916 | 0·924 | 0·931 | 0·939 | 0·946 | 0·953 |
| 23 | 0·911 | 0·919 | 0·927 | 0·934 | 0·942 | 0·950 | 0·957 | 0·964 | 0·972 |
| 24 | 0·928 | 0·936 | 0·944 | 0·952 | 0·960 | 0·967 | 0·975 | 0·982 | 0·989 |
| 25 | 0·945 | 0·953 | 0·961 | 0·969 | 0·976 | 0·984 | 0·991 | 0·999 | 1·006 |
| 26 | 0·961 | 0·969 | 0·977 | 0·984 | 0·992 | 1·000 | 1·007 | 1·014 | 1·022 |
| 27 | 0·976 | 0·984 | 0·992 | 1·000 | 1·007 | 1·015 | 1·022 | 1·030 | 1·037 |
| 28 | 0·990 | 0·998 | 1·006 | 1·014 | 1·022 | 1·030 | 1·037 | 1·044 | 1·051 |
| 29 | 1·004 | 1·012 | 1·020 | 1·028 | 1·036 | 1·044 | 1·051 | 1·058 | 1·065 |
| 30 | 1·018 | 1·026 | 1·034 | 1·042 | 1·049 | 1·057 | 1·064 | 1·072 | 1·079 |
| 32 | 1·043 | 1·051 | 1·059 | 1·067 | 1·075 | 1·082 | 1·090 | 1·097 | 1·104 |
| 34 | 1·066 | 1·075 | 1·083 | 1·090 | 1·098 | 1·106 | 1·113 | 1·120 | 1·128 |
| 36 | 1·088 | 1·096 | 1·104 | 1·112 | 1·120 | 1·127 | 1·135 | 1·142 | 1·149 |
| 38 | 1·108 | 1·116 | 1·124 | 1·132 | 1·140 | 1·147 | 1·155 | 1·162 | 1·169 |
| 40 | 1·127 | 1·135 | 1·143 | 1·151 | 1·159 | 1·166 | 1·174 | 1·181 | 1·188 |
| 42 | 1·145 | 1·153 | 1·161 | 1·169 | 1·176 | 1·184 | 1·191 | 1·198 | 1·206 |
| 44 | 1·161 | 1·169 | 1·177 | 1·185 | 1·193 | 1·200 | 1·208 | 1·215 | 1·222 |
| 46 | 1·176 | 1·184 | 1·192 | 1·200 | 1·208 | 1·215 | 1·223 | 1·230 | 1·237 |
| 48 | 1·190 | 1·198 | 1·206 | 1·214 | 1·222 | 1·229 | 1·237 | 1·244 | 1·251 |
| 50 | 1·204 | 1·212 | 1·220 | 1·227 | 1·235 | 1·243 | 1·250 | 1·257 | 1·265 |
| 52 | 1·216 | 1·224 | 1·232 | 1·240 | 1·247 | 1·255 | 1·262 | 1·270 | 1·277 |
| 54 | 1·227 | 1·235 | 1·243 | 1·251 | 1·259 | 1·266 | 1·274 | 1·281 | 1·288 |
| 56 | 1·238 | 1·246 | 1·254 | 1·262 | 1·270 | 1·277 | 1·285 | 1·292 | 1·299 |
| 58 | 1·248 | 1·256 | 1·264 | 1·272 | 1·279 | 1·287 | 1·294 | 1·302 | 1·309 |
| 60 | 1·258 | 1·266 | 1·274 | 1·282 | 1·290 | 1·297 | 1·305 | 1·312 | 1·319 |
| 62 | 1·265 | 1·274 | 1·282 | 1·289 | 1·297 | 1·305 | 1·312 | 1·319 | 1·327 |
| 64 | 1·273 | 1·281 | 1·289 | 1·297 | 1·305 | 1·312 | 1·320 | 1·327 | 1·334 |
| 66 | 1·280 | 1·288 | 1·296 | 1·304 | 1·312 | 1·320 | 1·327 | 1·334 | 1·341 |
| 68 | 1·287 | 1·295 | 1·303 | 1·311 | 1·318 | 1·326 | 1·333 | 1·341 | 1·348 |
| 70 | 1·293 | 1·301 | 1·309 | 1·317 | 1·324 | 1·332 | 1·339 | 1·347 | 1·354 |
| 72 | 1·298 | 1·306 | 1·314 | 1·322 | 1·330 | 1·337 | 1·345 | 1·352 | 1·359 |
| 74 | 1·303 | 1·311 | 1·319 | 1·327 | 1·334 | 1·342 | 1·349 | 1·356 | 1·364 |
| 76 | 1·307 | 1·315 | 1·323 | 1·331 | 1·338 | 1·346 | 1·353 | 1·361 | 1·368 |
| 78 | 1·310 | 1·318 | 1·326 | 1·334 | 1·342 | 1·349 | 1·357 | 1·364 | 1·371 |
| 80 | 1·313 | 1·321 | 1·329 | 1·337 | 1·345 | 1·352 | 1·360 | 1·367 | 1·374 |

## LOG. SINES TO TEN SECONDS.

| | 0° | | | | | | | 1° | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0″ | 10″ | 20″ | 30″ | 40″ | 50″ | 60″ | 0″ | 10″ | 20″ | ′ |
| 0 | — ∞ | 5·68557 | 5·98660 | 6·16270 | 6·28763 | 6·38454 | 6·46373 | 8·24186 | 8·24306 | 8·24426 | 59 |
| 1 | 6·46373 | 6·53067 | 6·58866 | 6·63982 | 6·68557 | 6·72697 | 6·76476 | 8·24903 | 8·25022 | 8·25140 | 58 |
| 2 | 6·76476 | 6·79952 | 6·83170 | 6·86167 | 6·88969 | 6·91602 | 6·94085 | 8·25609 | 8·25726 | 8·25842 | 57 |
| 3 | 6·94085 | 6·96433 | 6·98660 | 7·00779 | 7·02800 | 7·04730 | 7·06579 | 8·26304 | 8·26419 | 8·26533 | 56 |
| 4 | 7·06579 | 7·08351 | 7·10055 | 7·11694 | 7·13273 | 7·14797 | 7·16270 | 8·26988 | 8·27101 | 8·27214 | 55 |
| 5 | 7·16270 | 7·17694 | 7·19072 | 7·20409 | 7·21705 | 7·22964 | 7·24188 | 8·27661 | 8·27773 | 8·27883 | 54 |
| 6 | 7·24188 | 7·25378 | 7·26536 | 7·27664 | 7·28763 | 7·29836 | 7·30882 | 8·28324 | 8·28434 | 8·28543 | 53 |
| 7 | 7·30882 | 7·31904 | 7·32903 | 7·33879 | 7·34833 | 7·35767 | 7·36682 | 8·28977 | 8·29085 | 8·29193 | 52 |
| 8 | 7·36682 | 7·37577 | 7·38454 | 7·39314 | 7·40158 | 7·40985 | 7·41797 | 8·29621 | 8·29727 | 8·29833 | 51 |
| 9 | 7·41797 | 7·42594 | 7·43376 | 7·44145 | 7·44900 | 7·45643 | 7·46373 | 8·30255 | 8·30359 | 8·30464 | 50 |
| 10 | 7·46373 | 7·47090 | 7·47797 | 7·48491 | 7·49175 | 7·49849 | 7·50512 | 8·30879 | 8·30983 | 8·31086 | 49 |
| 11 | 7·50512 | 7·51165 | 7·51808 | 7·52442 | 7·53067 | 7·53683 | 7·54291 | 8·31495 | 8·31597 | 8·31699 | 48 |
| 12 | 7·54291 | 7·54890 | 7·55481 | 7·56064 | 7·56639 | 7·57206 | 7·57767 | 8·32103 | 8·32203 | 8·32303 | 47 |
| 13 | 7·57767 | 7·58320 | 7·58866 | 7·59406 | 7·59939 | 7·60465 | 7·60985 | 8·32702 | 8·32801 | 8·32899 | 46 |
| 14 | 7·60985 | 7·61499 | 7·62007 | 7·62509 | 7·63006 | 7·63496 | 7·63982 | 8·33292 | 8·33390 | 8·33488 | 45 |
| 15 | 7·63982 | 7·64461 | 7·64936 | 7·65406 | 7·65870 | 7·66330 | 7·66784 | 8·33875 | 8·33972 | 8·34068 | 44 |
| 16 | 7·66784 | 7·67235 | 7·67680 | 7·68121 | 7·68557 | 7·68989 | 7·69417 | 8·34450 | 8·34546 | 8·34640 | 43 |
| 17 | 7·69417 | 7·69841 | 7·70261 | 7·70676 | 7·71088 | 7·71496 | 7·71900 | 8·35018 | 8·35112 | 8·35206 | 42 |
| 18 | 7·71900 | 7·72300 | 7·72697 | 7·73090 | 7·73479 | 7·73865 | 7·74248 | 8·35578 | 8·35671 | 8·35764 | 41 |
| 19 | 7·74248 | 7·74627 | 7·75003 | 7·75376 | 7·75745 | 7·76112 | 7·76475 | 8·36132 | 8·36223 | 8·36314 | 40 |
| 20 | 7·76475 | 7·76836 | 7·77193 | 7·77548 | 7·77899 | 7·78248 | 7·78594 | 8·36678 | 8·36768 | 8·36858 | 39 |
| 21 | 7·78594 | 7·78938 | 7·79278 | 7·79616 | 7·79952 | 7·80284 | 7·80615 | 8·37217 | 8·37306 | 8·37395 | 38 |
| 22 | 7·80615 | 7·80942 | 7·81268 | 7·81591 | 7·81911 | 7·82229 | 7·82545 | 8·37750 | 8·37838 | 8·37926 | 37 |
| 23 | 7·82545 | 7·82859 | 7·83170 | 7·83479 | 7·83786 | 7·84091 | 7·84393 | 8·38276 | 8·38363 | 8·38450 | 36 |
| 24 | 7·84393 | 7·84694 | 7·84992 | 7·85289 | 7·85583 | 7·85876 | 7·86166 | 8·38796 | 8·38882 | 8·38968 | 35 |
| 25 | 7·86166 | 7·86455 | 7·86741 | 7·87026 | 7·87309 | 7·87590 | 7·87870 | 8·39310 | 8·39395 | 8·39480 | 34 |
| 26 | 7·87870 | 7·88147 | 7·88423 | 7·88697 | 7·88969 | 7·89240 | 7·89509 | 8·39818 | 8·39902 | 8·39986 | 33 |
| 27 | 7·89509 | 7·89776 | 7·90041 | 7·90305 | 7·90568 | 7·90829 | 7·91088 | 8·40320 | 8·40403 | 8·40486 | 32 |
| 28 | 7·91088 | 7·91346 | 7·91602 | 7·91857 | 7·92110 | 7·92362 | 7·92612 | 8·40816 | 8·40898 | 8·40980 | 31 |
| 29 | 7·92612 | 7·92861 | 7·93108 | 7·93354 | 7·93599 | 7·93842 | 7·94084 | 8·41307 | 8·41388 | 8·41469 | 30 |
| 30 | 7·94084 | 7·94325 | 7·94564 | 7·94802 | 7·95039 | 7·95274 | 7·95508 | 8·41792 | 8·41872 | 8·41952 | 29 |
| 31 | 7·95508 | 7·95741 | 7·95973 | 7·96203 | 7·96432 | 7·96660 | 7·96887 | 8·42272 | 8·42351 | 8·42430 | 28 |
| 32 | 7·96887 | 7·97113 | 7·97337 | 7·97560 | 7·97782 | 7·98003 | 7·98223 | 8·42746 | 8·42825 | 8·42903 | 27 |
| 33 | 7·98223 | 7·98442 | 7·98660 | 7·98876 | 7·99092 | 7·99306 | 7·99520 | 8·43216 | 8·43293 | 8·43371 | 26 |
| 34 | 7·99520 | 7·99732 | 7·99943 | 8·00154 | 8·00363 | 8·00571 | 8·00779 | 8·43680 | 8·43757 | 8·43834 | 25 |
| 35 | 8·00779 | 8·00985 | 8·01190 | 8·01395 | 8·01598 | 8·01801 | 8·02002 | 8·44139 | 8·44216 | 8·44292 | 24 |
| 36 | 8·02002 | 8·02203 | 8·02402 | 8·02601 | 8·02799 | 8·02996 | 8·03192 | 8·44594 | 8·44669 | 8·44745 | 23 |
| 37 | 8·03192 | 8·03387 | 8·03581 | 8·03775 | 8·03967 | 8·04159 | 8·04350 | 8·45044 | 8·45119 | 8·45193 | 22 |
| 38 | 8·04350 | 8·04540 | 8·04729 | 8·04918 | 8·05105 | 8·05292 | 8·05478 | 8·45489 | 8·45563 | 8·45637 | 21 |
| 39 | 8·05478 | 8·05663 | 8·05848 | 8·06031 | 8·06214 | 8·06396 | 8·06578 | 8·45930 | 8·46003 | 8·46076 | 20 |
| 40 | 8·06578 | 8·06758 | 8·06938 | 8·07117 | 8·07295 | 8·07473 | 8·07650 | 8·46366 | 8·46439 | 8·46511 | 19 |
| 41 | 8·07650 | 8·07826 | 8·08002 | 8·08176 | 8·08350 | 8·08524 | 8·08696 | 8·46799 | 8·46870 | 8·46942 | 18 |
| 42 | 8·08696 | 8·08868 | 8·09040 | 8·09210 | 8·09380 | 8·09550 | 8·09718 | 8·47226 | 8·47297 | 8·47368 | 17 |
| 43 | 8·09718 | 8·09886 | 8·10054 | 8·10220 | 8·10386 | 8·10552 | 8·10717 | 8·47650 | 8·47720 | 8·47790 | 16 |
| 44 | 8·10717 | 8·10881 | 8·11044 | 8·11207 | 8·11370 | 8·11531 | 8·11693 | 8·48069 | 8·48139 | 8·48208 | 15 |
| 45 | 8·11693 | 8·11853 | 8·12013 | 8·12172 | 8·12331 | 8·12489 | 8·12647 | 8·48485 | 8·48554 | 8·48622 | 14 |
| 46 | 8·12647 | 8·12804 | 8·12961 | 8·13117 | 8·13272 | 8·13427 | 8·13581 | 8·48896 | 8·48965 | 8·49033 | 13 |
| 47 | 8·13581 | 8·13735 | 8·13888 | 8·14041 | 8·14193 | 8·14344 | 8·14495 | 8·49304 | 8·49372 | 8·49439 | 12 |
| 48 | 8·14495 | 8·14646 | 8·14796 | 8·14945 | 8·15094 | 8·15243 | 8·15391 | 8·49708 | 8·49775 | 8·49842 | 11 |
| 49 | 8·15391 | 8·15538 | 8·15685 | 8·15832 | 8·15978 | 8·16123 | 8·16268 | 8·50108 | 8·50174 | 8·50241 | 10 |
| 50 | 8·16268 | 8·16413 | 8·16557 | 8·16700 | 8·16843 | 8·16986 | 8·17128 | 8·50504 | 8·50570 | 8·50636 | 9 |
| 51 | 8·17128 | 8·17270 | 8·17411 | 8·17552 | 8·17692 | 8·17832 | 8·17971 | 8·50897 | 8·50963 | 8·51028 | 8 |
| 52 | 8·17971 | 8·18110 | 8·18249 | 8·18387 | 8·18525 | 8·18662 | 8·18798 | 8·51287 | 8·51351 | 8·51416 | 7 |
| 53 | 8·18798 | 8·18935 | 8·19071 | 8·19206 | 8·19341 | 8·19476 | 8·19610 | 8·51673 | 8·51737 | 8·51801 | 6 |
| 54 | 8·19610 | 8·19744 | 8·19877 | 8·20010 | 8·20143 | 8·20275 | 8·20407 | 8·52055 | 8·52119 | 8·52182 | 5 |
| 55 | 8·20407 | 8·20538 | 8·20669 | 8·20800 | 8·20930 | 8·21060 | 8·21189 | 8·52434 | 8·52497 | 8·52560 | 4 |
| 56 | 8·21189 | 8·21319 | 8·21447 | 8·21576 | 8·21703 | 8·21831 | 8·21958 | 8·52810 | 8·52873 | 8·52935 | 3 |
| 57 | 8·21958 | 8·22085 | 8·22211 | 8·22337 | 8·22463 | 8·22588 | 8·22713 | 8·53183 | 8·53245 | 8·53306 | 2 |
| 58 | 8·22713 | 8·22838 | 8·22962 | 8·23086 | 8·23210 | 8·23333 | 8·23456 | 8·53552 | 8·53614 | 8·53675 | 1 |
| 59 | 8·23456 | 8·23578 | 8·23700 | 8·23822 | 8·23944 | 8·24065 | 8·24186 | 8·53919 | 8·53979 | 8·54040 | 0 |
| ′ | 60″ | 50″ | 40″ | 30″ | 20″ | 10″ | 0″ | 60″ | 50″ | 40″ | ′ |
| | 89° | | | | | | | 88° | | | |

## LOG. COSINES.

## LOG. SINES TO TEN SECONDS.

| ′ | 1° | | | | 2° | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30″ | 40″ | 50″ | 60″ | 0″ | 10″ | 20″ | 30″ | 40″ | 50″ | |
| 0 | 8·24546 | 8·24665 | 8·24785 | 8·24903 | 8·54282 | 8·54342 | 8·54402 | 8·54462 | 8·54522 | 8·54582 | 59 |
| 1 | 8·25258 | 8·25375 | 8·25493 | 8 25609 | 8 54642 | 8·54702 | 8·54762 | 8·54821 | 8·54881 | 8·54940 | 58 |
| 2 | 8·25958 | 8·26074 | 8·26189 | 8·26304 | 8 54999 | 8·54059 | 8·55118 | 8·55177 | 8·55236 | 8·55295 | 57 |
| 3 | 8 26648 | 8·26761 | 8·26875 | 8·26988 | 8 55354 | 8 55413 | 8·55471 | 8·55530 | 8·55589 | 8·55647 | 56 |
| 4 | 8 27326 | 8·27438 | 8·27550 | 8 27661 | 8 55705 | 8 55764 | 8 55822 | 8·55880 | 8·55938 | 8·55996 | 55 |
| 5 | 8·27994 | 8·28104 | 8 28215 | 8 28324 | 8·56054 | 8 56112 | 8 56170 | 8·56227 | 8·56285 | 8·56342 | 54 |
| 6 | 8·28652 | 8·28761 | 8·28869 | 8 28977 | 8·56400 | 8 56457 | 8 56515 | 8·56572 | 8 56629 | 8·56686 | 53 |
| 7 | 8·29300 | 8·29407 | 8·29514 | 8 29621 | 8·56743 | 8 56800 | 8 56857 | 8·56914 | 8 56970 | 8·57027 | 52 |
| 8 | 8·29939 | 8 30044 | 8·30150 | 8 30255 | 8·57084 | 8·57140 | 8·57196 | 8·57253 | 8 57309 | 8·57365 | 51 |
| 9 | 8·30568 | 8·30672 | 8 30776 | 8 30879 | 8·57421 | 8 57477 | 8·57533 | 8·57589 | 8·57645 | 8·57701 | 50 |
| 10 | 8 31188 | 8 31291 | 8 31393 | 8 31495 | 8 57757 | 8·57812 | 8·57868 | 8·57923 | 8·57979 | 8·58034 | 49 |
| 11 | 8 31800 | 8·31901 | 8 32002 | 8·32103 | 8 58089 | 8 58144 | 8·58200 | 8·58255 | 8·58310 | 8·58364 | 48 |
| 12 | 8 32403 | 8 32503 | 8 32602 | 8 32702 | 8·58419 | 8·58474 | 8·58529 | 8·58583 | 8·58638 | 8·58693 | 47 |
| 13 | 8·32998 | 8 33096 | 8 33195 | 8 33292 | 8 58747 | 8 58801 | 8·58856 | 8·58910 | 8 58964 | 8·59018 | 46 |
| 14 | 8 33585 | 8·33682 | 8 33779 | 8·33875 | 8 59072 | 8 59126 | 8·59180 | 8·59234 | 8·59288 | 8·59341 | 45 |
| 15 | 8 34164 | 8·34260 | 8 34355 | 8 34450 | 8 59395 | 8 59448 | 8·59502 | 8·59555 | 8·59609 | 8·59662 | 44 |
| 16 | 8 34735 | 8 34830 | 8 34924 | 8 35018 | 8 59715 | 8·59768 | 8·59821 | 8·59874 | 8·59927 | 8·59980 | 43 |
| 17 | 8·35299 | 8 35392 | 8 35485 | 8·35578 | 8 60033 | 8·60086 | 8·60139 | 8·60191 | 8 60244 | 8·60296 | 42 |
| 18 | 8·35856 | 8 35948 | 8 36040 | 8 36132 | 8 60349 | 8·60401 | 8·60454 | 8·60506 | 8·60558 | 8·60610 | 41 |
| 19 | 8 36405 | 8 36496 | 8 36587 | 8·36678 | 8·60662 | 8·60714 | 8·60766 | 8·60818 | 8·60870 | 8·60922 | 40 |
| 20 | 8 36948 | 8 37038 | 8 37128 | 8 37217 | 8 60973 | 8 61025 | 8·61077 | 8·61128 | 8 61180 | 8·61231 | 39 |
| 21 | 8·37484 | 8·37573 | 8·37662 | 8·37750 | 8·61282 | 8·61334 | 8·61385 | 8·61436 | 8·61487 | 8·61538 | 38 |
| 22 | 8·38014 | 8 38101 | 8·38189 | 8·38276 | 8 61589 | 8·61640 | 8·61691 | 8·61742 | 8·61792 | 8·61843 | 37 |
| 23 | 8 38537 | 8 38624 | 8·38710 | 8 38796 | 8 61894 | 8·61944 | 8·61995 | 8·62045 | 8·62096 | 8·62146 | 36 |
| 24 | 8 39054 | 8 39139 | 8 39225 | 8·39310 | 8 62196 | 8·62246 | 8·62297 | 8·62347 | 8·62397 | 8·62447 | 35 |
| 25 | 8 39565 | 8·39649 | 8 39734 | 8·39818 | 8·62497 | 8·62546 | 8·62596 | 8·62646 | 8·62696 | 8·62745 | 34 |
| 26 | 8 40070 | 8 40153 | 8 40237 | 8·40320 | 8·62795 | 8·62844 | 8·62894 | 8·62943 | 8·62993 | 8·63042 | 33 |
| 27 | 8·40569 | 8·40651 | 8 40734 | 8·40816 | 8·63091 | 8·63140 | 8·63189 | 8·63238 | 8·63287 | 8·63336 | 32 |
| 28 | 8·41062 | 8·41144 | 8·41225 | 8·41307 | 8·63385 | 8·63434 | 8·63483 | 8·63532 | 8·63580 | 8·63629 | 31 |
| 29 | 8 41550 | 8·41631 | 8·41711 | 8·41792 | 8·63678 | 8·63726 | 8·63775 | 8·63823 | 8·63871 | 8·63920 | 30 |
| 30 | 8 42032 | 8 42112 | 8 42192 | 8 42272 | 8·63968 | 8·64016 | 8 64064 | 8·64112 | 8·64160 | 8·64208 | 29 |
| 31 | 8 42510 | 8·42589 | 8 42667 | 8·42746 | 8·64256 | 8·64304 | 8·64352 | 8·64400 | 8·64448 | 8·64495 | 28 |
| 32 | 8·42982 | 8·43060 | 8·43138 | 8·43216 | 8·64543 | 8 64590 | 8·64638 | 8·64685 | 8·64733 | 8·64780 | 27 |
| 33 | 8·43448 | 8 43526 | 8 43603 | 8·43680 | 8·64827 | 8·64875 | 8·64922 | 8·64969 | 8·65016 | 8·65063 | 26 |
| 34 | 8 43910 | 8·43987 | 8·44063 | 8·44139 | 8·65110 | 8·65157 | 8·65204 | 8·65251 | 8·65298 | 8·65344 | 25 |
| 35 | 8·44367 | 8 44443 | 8·44519 | 8 44594 | 8·65391 | 8·65438 | 8·65484 | 8·65531 | 8·65577 | 8·65624 | 24 |
| 36 | 8 44820 | 8·44895 | 8 44969 | 8 45044 | 8·65670 | 8·65717 | 8·65763 | 8·65809 | 8·65855 | 8·65901 | 23 |
| 37 | 8 45267 | 8·45341 | 8·45415 | 8 45489 | 8·65947 | 8·65994 | 8·66040 | 8·66085 | 8·66131 | 8·66177 | 22 |
| 38 | 8·45710 | 8·45784 | 8·45857 | 8·45930 | 8 66223 | 8·66269 | 8·66314 | 8·66360 | 8·66406 | 8·66451 | 21 |
| 39 | 8·46149 | 8·46222 | 8·46294 | 8·46366 | 8 66497 | 8·66542 | 8·66588 | 8·66633 | 8·66678 | 8·66724 | 20 |
| 40 | 8·46583 | 8 46655 | 8 46727 | 8 46799 | 8 66769 | 8·66814 | 8 66859 | 8·66904 | 8·66949 | 8·66994 | 19 |
| 41 | 8·47013 | 8·47084 | 8·47155 | 8·47226 | 8·67039 | 8·67084 | 8·67129 | 8·67174 | 8·67219 | 8·67263 | 18 |
| 42 | 8·47439 | 8·47509 | 8·47580 | 8·47650 | 8·67308 | 8·67353 | 8·67397 | 8·67442 | 8·67486 | 8·67531 | 17 |
| 43 | 8·47860 | 8·47930 | 8·48000 | 8·48069 | 8·67575 | 8 67619 | 8·67664 | 8·67708 | 8·67752 | 8·67796 | 16 |
| 44 | 8·48278 | 8·48347 | 8·48416 | 8·48485 | 8·67841 | 8·67885 | 8·67929 | 8·67973 | 8·68017 | 8·68060 | 15 |
| 45 | 8·48691 | 8·48760 | 8 48828 | 8·48896 | 8·68104 | 8·68148 | 8·68192 | 8·68236 | 8·68279 | 8·68323 | 14 |
| 46 | 8·49101 | 8·49169 | 8·49236 | 8 49304 | 8·68367 | 8·68410 | 8·68454 | 8·68497 | 8·68540 | 8 68584 | 13 |
| 47 | 8·49506 | 8·49574 | 8·49641 | 8·49708 | 8 68627 | 8 68670 | 8·68714 | 8·68757 | 8·68800 | 8·68843 | 12 |
| 48 | 8·49908 | 8·49975 | 8·50042 | 8·50108 | 8·68886 | 8·68929 | 8·68972 | 8·69015 | 8·69058 | 8·69101 | 11 |
| 49 | 8·50307 | 8·50373 | 8·50439 | 8·50504 | 8·69144 | 8·69187 | 8·69229 | 8·69272 | 8·69315 | 8·69357 | 10 |
| 50 | 8·50701 | 8 50767 | 8·50832 | 8 50897 | 8·69400 | 8·69442 | 8·69485 | 8 69527 | 8 69570 | 8·69612 | 9 |
| 51 | 8·51092 | 8·51157 | 8·51222 | 8·51287 | 8·69654 | 8·69697 | 8·69739 | 8 69781 | 8·69823 | 8·69865 | 8 |
| 52 | 8·51480 | 8·51544 | 8·51609 | 8 51673 | 8·69907 | 8·69949 | 8·69991 | 8·70033 | 8·70075 | 8·70117 | 7 |
| 53 | 8·51864 | 8·51928 | 8·51992 | 8 52055 | 8·70159 | 8·70201 | 8·70242 | 8·70284 | 8·70326 | 8·70367 | 6 |
| 54 | 8 52245 | 8·52308 | 8·52371 | 8·52434 | 8·70409 | 8·70451 | 8·70492 | 8·70534 | 8·70575 | 8·70616 | 5 |
| 55 | 8 52623 | 8·52685 | 8·52748 | 8·52810 | 8·70658 | 8·70699 | 8·70740 | 8·70781 | 8·70823 | 8·70864 | 4 |
| 56 | 8 52997 | 8·53059 | 8·53121 | 8·53183 | 8·70905 | 8·70946 | 8·70987 | 8·71028 | 8·71069 | 8·71110 | 3 |
| 57 | 8 53368 | 8·53429 | 8·53491 | 8 53552 | 8·71151 | 8·71192 | 8·71232 | 8·71273 | 8·71314 | 8·71355 | 2 |
| 58 | 8 53736 | 8·53797 | 8·53858 | 8 53919 | 8·71395 | 8·71436 | 8·71476 | 8·71517 | 8·71557 | 8·71598 | 1 |
| 59 | 8·54101 | 8·54161 | 8·54222 | 8·54282 | 8·71638 | 8·71679 | 8·71719 | 8·71759 | 8·71800 | 8·71840 | 0 |
| ′ | 30″ | 20″ | 10″ | 0″ | 60″ | 50″ | 40″ | 30″ | 20″ | 10″ | ′ |
| | 88° | | | | 87° | | | | | | |

## LOG. COSINES.

## LOG. SINES TO TEN SECONDS.

| ′ | 2° | 3° | | | | | | | 4° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60″ | 0″ | 10″ | 20″ | 30″ | 40″ | 50″ | 60″ | 0″ | 10″ | |
| 0 | 8·54642 | 8·71880 | 8·71920 | 8·71960 | 8·72000 | 8·72040 | 8·72080 | 8·72120 | 8·84358 | 8 84389 | 59 |
| 1 | 8 54999 | 8 72120 | 8·72160 | 8·72200 | 8·72240 | 8·72280 | 8·72320 | 8·72359 | 8·84539 | 8 84569 | 58 |
| 2 | 8·55354 | 8 72359 | 8·72399 | 8·72439 | 8·72479 | 8·72518 | 8·72558 | 8·72597 | 8·84718 | 8 84748 | 57 |
| 3 | 8 55705 | 8 72597 | 8·72637 | 8·72676 | 8·72716 | 8·72755 | 8·72794 | 8·72834 | 8·84897 | 8·84927 | 56 |
| 4 | 8 56054 | 8·72834 | 8·72873 | 8·72912 | 8·72951 | 8·72991 | 8·73030 | 8·73069 | 8·85075 | 8 85105 | 55 |
| 5 | 8·56400 | 8·73069 | 8 73108 | 8 73147 | 8·73186 | 8·73225 | 8·73264 | 8·73303 | 8·85252 | 8·85282 | 54 |
| 6 | 8 56743 | 8 73303 | 8·73342 | 8·73380 | 8·73419 | 8·73458 | 8·73497 | 8·73535 | 8·85429 | 8·85458 | 53 |
| 7 | 8·57084 | 8 73535 | 8·73574 | 8·73613 | 8·73651 | 8·73690 | 8·73728 | 8·73767 | 8·85605 | 8 85634 | 52 |
| 8 | 8·57421 | 8 73767 | 8·73805 | 8·73844 | 8·73882 | 8·73920 | 8·73959 | 8·73997 | 8·85780 | 8·85809 | 51 |
| 9 | 8·57757 | 8 73997 | 8·74035 | 8·74074 | 8·74112 | 8·74150 | 8·74188 | 8·74226 | 8·85955 | 8·85984 | 50 |
| 10 | 8·58089 | 8·74226 | 8·74264 | 8·74302 | 8·74340 | 8·74378 | 8·74416 | 8·74454 | 8·86128 | 8 86157 | 49 |
| 11 | 8·58419 | 8 74454 | 8·74491 | 8 74529 | 8·74567 | 8·74605 | 8·74642 | 8·74680 | 8·86301 | 8·86330 | 48 |
| 12 | 8 58747 | 8·74680 | 8·74718 | 8·74755 | 8·74793 | 8·74831 | 8·74868 | 8·74906 | 8·86474 | 8 86502 | 47 |
| 13 | 8 59072 | 8·74906 | 8·74943 | 8·74980 | 8·75018 | 8·75055 | 8·75092 | 8·75130 | 8·86645 | 8 86674 | 46 |
| 14 | 8·59395 | 8·75130 | 8·75167 | 8·75204 | 8·75241 | 8·75279 | 8·75316 | 8·75353 | 8·86816 | 8 86845 | 45 |
| 15 | 8 59715 | 8·75353 | 8·75390 | 8·75427 | 8·75464 | 8·75501 | 8·75538 | 8·75575 | 8·86987 | 8 87015 | 44 |
| 16 | 8·60033 | 8·75575 | 8·75612 | 8·75648 | 8·75685 | 8·75722 | 8·75759 | 8·75795 | 8·87156 | 8·87185 | 43 |
| 17 | 8·60349 | 8·75795 | 8·75832 | 8·75869 | 8 75905 | 8·75942 | 8·75979 | 8·76015 | 8·87325 | 8·87354 | 42 |
| 18 | 8·60662 | 8·76015 | 8·76052 | 8·76088 | 8·76125 | 8·76161 | 8·76197 | 8·76234 | 8·87494 | 8 87522 | 41 |
| 19 | 8·60973 | 8·76234 | 8·76270 | 8·76306 | 8·76343 | 8·76379 | 8·76415 | 8·76451 | 8·87662 | 8·87689 | 40 |
| 20 | 8 61282 | 8 76451 | 8·76487 | 8·76523 | 8·76559 | 8·76595 | 8·76631 | 8·76667 | 8·87829 | 8 87856 | 39 |
| 21 | 8·61589 | 8·76667 | 8·76703 | 8·76739 | 8·76775 | 8·76811 | 8·76847 | 8·76883 | 8·87998 | 8·87023 | 38 |
| 22 | 8·61894 | 8·76883 | 8·76919 | 8·76954 | 8·76990 | 8·77026 | 8·77061 | 8·77097 | 8·88161 | 8·88188 | 37 |
| 23 | 8·62196 | 8·77097 | 8·77133 | 8·77168 | 8·77204 | 8·77239 | 8·77275 | 8·77310 | 8·88326 | 8·88353 | 36 |
| 24 | 8·62497 | 8·77310 | 8·77346 | 8·77381 | 8·77416 | 8·77452 | 8·77487 | 8·77522 | 8·88490 | 8 88518 | 35 |
| 25 | 8·62795 | 8·77522 | 8·77558 | 8·77593 | 8·77628 | 8·77663 | 8·77698 | 8·77733 | 8·88654 | 8 88681 | 34 |
| 26 | 8 63091 | 8·77733 | 8·77768 | 8·77803 | 8·77839 | 8·77873 | 8·77908 | 8·77943 | 8·88817 | 8·88845 | 33 |
| 27 | 8 63385 | 8·77943 | 8·77978 | 8·78013 | 8·78048 | 8·78083 | 8·78118 | 8·78152 | 8·88980 | 8 89007 | 32 |
| 28 | 8·63678 | 8·78152 | 8·78187 | 8·78222 | 8·78257 | 8·78291 | 8·78326 | 8·78360 | 8·89142 | 8·89169 | 31 |
| 29 | 8 63968 | 8·78360 | 8·78395 | 8·78430 | 8·78464 | 8·78499 | 8·78533 | 8·78568 | 8·89304 | 8·89330 | 30 |
| 30 | 8·64256 | 8·78568 | 8·78602 | 8·78636 | 8·78671 | 8·78705 | 8·78739 | 8·78774 | 8 89464 | 8 89491 | 29 |
| 31 | 8·64543 | 8·78774 | 8·78808 | 8·78842 | 8·78876 | 8·78910 | 8·78945 | 8·78979 | 8·89625 | 8·89651 | 28 |
| 32 | 8·64827 | 8·78979 | 8·79013 | 8·79047 | 8·79081 | 8·79115 | 8·79149 | 8·79183 | 8·89784 | 8 89811 | 27 |
| 33 | 8·65110 | 8·79183 | 8·79217 | 8·79251 | 8·79284 | 8·79318 | 8·79352 | 8·79386 | 8·89943 | 8·89970 | 26 |
| 34 | 8·65391 | 8·79386 | 8·79420 | 8·79453 | 8·79487 | 8·79521 | 8·79555 | 8·79588 | 8·90102 | 8·90128 | 25 |
| 35 | 8·65670 | 8·79588 | 8·79622 | 8·79655 | 8·79689 | 8·79722 | 8·79756 | 8·79789 | 8·90260 | 8 90286 | 24 |
| 36 | 8·65947 | 8·79789 | 8·79823 | 8·79856 | 8·79890 | 8·79923 | 8·79956 | 8·79990 | 8·90417 | 8·90443 | 23 |
| 37 | 8·66223 | 8·79990 | 8·80023 | 8·80056 | 8·80090 | 8·80123 | 8·80156 | 8·80189 | 8·90574 | 8·90600 | 22 |
| 38 | 8·66497 | 8·80189 | 8·80222 | 8·80255 | 8·80289 | 8·80322 | 8·80355 | 8·80388 | 8·90730 | 8·90756 | 21 |
| 39 | 8·66769 | 8·80388 | 8·80421 | 8·80454 | 8·80487 | 8·80519 | 8·80552 | 8·80585 | 8·90885 | 8·90911 | 20 |
| 40 | 8·67039 | 8·80585 | 8·80618 | 8·80651 | 8·80684 | 8·80716 | 8·80749 | 8·80782 | 8·91040 | 8 91066 | 19 |
| 41 | 8·67308 | 8·80782 | 8·80815 | 8·80847 | 8·80880 | 8·80913 | 8·80945 | 8·80978 | 8·91195 | 8·91221 | 18 |
| 42 | 8·67575 | 8·80978 | 8·81010 | 8·81043 | 8·81075 | 8·81108 | 8·81140 | 8·81173 | 8·91349 | 8·91374 | 17 |
| 43 | 8·67841 | 8·81173 | 8·81205 | 8·81237 | 8·81270 | 8·81302 | 8·81334 | 8·81367 | 8·91502 | 8·91528 | 16 |
| 44 | 8·68104 | 8·81367 | 8·81399 | 8·81431 | 8·81463 | 8·81496 | 8·81528 | 8·81560 | 8·91655 | 8·91680 | 15 |
| 45 | 8·68367 | 8·81560 | 8·81592 | 8·81624 | 8·81656 | 8·81688 | 8·81720 | 8·81752 | 8·91807 | 8·91833 | 14 |
| 46 | 8·68627 | 8·81752 | 8·81784 | 8·81816 | 8·81848 | 8·81880 | 8·81912 | 8·81944 | 8·91959 | 8·91984 | 13 |
| 47 | 8·68886 | 8·81944 | 8·81975 | 8·82007 | 8·82039 | 8·82071 | 8·82103 | 8·82134 | 8·92110 | 8·92135 | 12 |
| 48 | 8·69144 | 8·82134 | 8·82166 | 8·82198 | 8·82229 | 8·82261 | 8·82292 | 8·82324 | 8·92261 | 8·92286 | 11 |
| 49 | 8·69400 | 8·82324 | 8·82356 | 8·82387 | 8·82419 | 8·82450 | 8·82482 | 8·82513 | 8·92411 | 8·92436 | 10 |
| 50 | 8·69654 | 8·82513 | 8·82544 | 8·82576 | 8·82607 | 8·82639 | 8·82670 | 8·82701 | 8·92561 | 8·92586 | 9 |
| 51 | 8·69907 | 8·82701 | 8·82732 | 8·82764 | 8·82795 | 8·82826 | 8·82857 | 8·82888 | 8·92710 | 8·92735 | 8 |
| 52 | 8·70159 | 8·82888 | 8·82920 | 8·82951 | 8·82982 | 8·83013 | 8·83044 | 8·83075 | 8·92859 | 8·92883 | 7 |
| 53 | 8·70409 | 8·83075 | 8·83106 | 8·83137 | 8·83168 | 8·83199 | 8·83230 | 8·83261 | 8·93007 | 8·93031 | 6 |
| 54 | 8·70658 | 8·83261 | 8·83292 | 8·83322 | 8·83353 | 8·83384 | 8 83415 | 8·83446 | 8·93154 | 8·93179 | 5 |
| 55 | 8·70905 | 8·83446 | 8·83476 | 8·83507 | 8·83538 | 8·83568 | 8·83599 | 8·83630 | 8·93302 | 8·93326 | 4 |
| 56 | 8·71151 | 8·83630 | 8·83660 | 8·83691 | 8·83721 | 8·83752 | 8·83783 | 8·83813 | 8·93448 | 8·93472 | 3 |
| 57 | 8·71395 | 8·83813 | 8·83844 | 8·83874 | 8 83904 | 8·83935 | 8·83965 | 8·83996 | 8·93594 | 8·93619 | 2 |
| 58 | 8·71638 | 8·83996 | 8·84026 | 8·84056 | 8·84087 | 8·84117 | 8·84147 | 8·84177 | 8·93740 | 8·93764 | 1 |
| 59 | 8·71880 | 8·84177 | 8·84208 | 8·84238 | 8·84268 | 8·84298 | 8·84328 | 8·84358 | 8·93885 | 8·93909 | 0 |
| ′ | 0 | 60″ | 50″ | 40″ | 30″ | 20″ | 10″ | 0″ | 60″ | 50″ | ′ |
| | 87° | 86° | | | | | | | 85° | | |

LOG. COSINES.

## LOG. SINES TO TEN SECONDS.

| ′ | 40° | | | | | 50° | | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20″ | 30″ | 40″ | 50″ | 60″ | 0″ | 20″ | 30″ | 40″ | 60″ | |
| 0 | 8 84419 | 8 84449 | 8 84479 | 8 84509 | 8 84539 | 8 94030 | 8 94078 | 8 94102 | 8 94126 | 8 94174 | 59 |
| 1 | 8 84599 | 8 84629 | 8 84659 | 8 84688 | 8 84718 | 8 94174 | 8 94222 | 8 94246 | 8·94270 | 8 94317 | 58 |
| 2 | 8 84778 | 8 84808 | 8 84838 | 8 84867 | 8 84897 | 8 94317 | 8 94365 | 8 94389 | 8 94413 | 8 94461 | 57 |
| 3 | 8 84957 | 8 84986 | 8 85016 | 8 85046 | 8 85075 | 8 94461 | 8 94508 | 8 94532 | 8·94556 | 8 94603 | 56 |
| 4 | 8 85134 | 8 85164 | 8 85193 | 8 85223 | 8 85252 | 8 94603 | 8 94651 | 8 94675 | 8·94698 | 8 94746 | 55 |
| 5 | 8 85311 | 8 85341 | 8 85370 | 8 85400 | 8 85429 | 8 94746 | 8 94793 | 8 94817 | 8·94840 | 8 94887 | 54 |
| 6 | 8 85488 | 8 85517 | 8 85546 | 8 85576 | 8 85605 | 8 94887 | 8 94935 | 8 94958 | 8·94982 | 8 95029 | 53 |
| 7 | 8 85663 | 8 85693 | 8 85722 | 8 85751 | 8 85780 | 8·95029 | 8 95076 | 8 95099 | 8 95123 | 8 95170 | 52 |
| 8 | 8 85838 | 8 85867 | 8 85896 | 8 85926 | 8 85955 | 8 95170 | 8 95216 | 8 95240 | 8 95263 | 8·95310 | 51 |
| 9 | 8 86013 | 8 86042 | 8 86070 | 8 86099 | 8 86128 | 8 95310 | 8·95357 | 8 95380 | 8·95403 | 8 95450 | 50 |
| 10 | 8 86186 | 8 86215 | 8 86244 | 8 86273 | 8 86301 | 8 95450 | 8 95496 | 8 95520 | 8·95543 | 8 95589 | 49 |
| 11 | 8 86359 | 8 86388 | 8 86416 | 8·86445 | 8 86474 | 8 95589 | 8 95636 | 8 95659 | 8·95682 | 8 95728 | 48 |
| 12 | 8 86531 | 8 86560 | 8 86588 | 8 86617 | 8 86645 | 8 95728 | 8 95775 | 8 95798 | 8·95821 | 8 95867 | 47 |
| 13 | 8 86703 | 8 86731 | 8 86760 | 8 86788 | 8 86816 | 8 95867 | 8 95913 | 8 95936 | 8·95959 | 8 96005 | 46 |
| 14 | 8 86873 | 8 86902 | 8 86930 | 8 86958 | 8 86987 | 8 96005 | 8 96051 | 8 96074 | 8·96097 | 8·96143 | 45 |
| 15 | 8 87043 | 8 87072 | 8 87100 | 8 87128 | 8 87156 | 8 96143 | 8 96189 | 8 96212 | 8·96234 | 8·96280 | 44 |
| 16 | 8 87213 | 8 87241 | 8 87269 | 8 87297 | 8 87325 | 8 96280 | 8 96326 | 8 96349 | 8·96371 | 8·96417 | 43 |
| 17 | 8 87382 | 8 87410 | 8 87438 | 8 87466 | 8 87494 | 8 96417 | 8 96462 | 8 96485 | 8·96508 | 8·96553 | 42 |
| 18 | 8 87550 | 8 87578 | 8 87606 | 8 87634 | 8 87661 | 8 96553 | 8 96599 | 8 96621 | 8·96644 | 8·96689 | 41 |
| 19 | 8 87717 | 8 87745 | 8 87773 | 8·87801 | 8 87829 | 8 96689 | 8 96735 | 8 96757 | 8·96780 | 8·96825 | 40 |
| 20 | 8 87884 | 8 87912 | 8 87940 | 8 87967 | 8 87995 | 8 96825 | 8 96870 | 8 96892 | 8·96915 | 8 96960 | 39 |
| 21 | 8 88050 | 8 88078 | 8 88106 | 8 88133 | 8 88161 | 8 96960 | 8 97005 | 8 97027 | 8·97050 | 8 97095 | 38 |
| 22 | 8 88216 | 8 88243 | 8 88271 | 8 88298 | 8 88326 | 8 97095 | 8 97139 | 8 97162 | 8·97184 | 8 97229 | 37 |
| 23 | 8·88381 | 8 88408 | 8 88436 | 8 88463 | 8 88490 | 8 97229 | 8 97274 | 8 97296 | 8·97318 | 8 97363 | 36 |
| 24 | 8 88545 | 8 88572 | 8 88600 | 8 88627 | 8 88654 | 8 97363 | 8 97407 | 8 97430 | 8·97452 | 8 97496 | 35 |
| 25 | 8 88709 | 8 88736 | 8 88763 | 8 88790 | 8 88817 | 8 97496 | 8 97541 | 8 97563 | 8·97585 | 8 97629 | 34 |
| 26 | 8 88872 | 8 88899 | 8 88926 | 8 88953 | 8 88980 | 8 97629 | 8 97674 | 8 97696 | 8·97718 | 8 97762 | 33 |
| 27 | 8 89034 | 8 89061 | 8 89088 | 8 89115 | 8 89142 | 8 97762 | 8 97806 | 8 97828 | 8·97850 | 8 97894 | 32 |
| 28 | 8 89196 | 8 89223 | 8 89250 | 8 89277 | 8 89304 | 8 97894 | 8 97938 | 8 97960 | 8·97982 | 8 98026 | 31 |
| 29 | 8 89357 | 8 89384 | 8 89411 | 8 89438 | 8·89464 | 8 98026 | 8 98070 | 8 98092 | 8·98114 | 8 98157 | 30 |
| 30 | 8 89518 | 8 89545 | 8 89571 | 8 89598 | 8 89625 | 8 98157 | 8 98201 | 8 98223 | 8 98245 | 8·98288 | 29 |
| 31 | 8 89678 | 8 89704 | 8 89731 | 8 89758 | 8 89784 | 8 98288 | 8 98332 | 8 98354 | 8·98375 | 8·98419 | 28 |
| 32 | 8 89837 | 8 89864 | 8·89890 | 8 89917 | 8 89943 | 8 98419 | 8 98462 | 8 98484 | 8·98506 | 8 98549 | 27 |
| 33 | 8 89996 | 8 90023 | 8 90049 | 8 90075 | 8 90102 | 8 98549 | 8 98592 | 8 98614 | 8·98636 | 8 98679 | 26 |
| 34 | 8 90154 | 8 90181 | 8 90207 | 8 90233 | 8 90260 | 8 98679 | 8 98722 | 8 98744 | 8·98765 | 8·98808 | 25 |
| 35 | 8 90312 | 8 90338 | 8 90364 | 8 90391 | 8 90417 | 8·98808 | 8 98851 | 8 98873 | 8·98894 | 8 98937 | 24 |
| 36 | 8 90469 | 8 90495 | 8 90521 | 8 90547 | 8 90574 | 8 98937 | 8 98980 | 8 99002 | 8·99023 | 8 99066 | 23 |
| 37 | 8 90626 | 8 90652 | 8 90678 | 8 90704 | 8 90730 | 8 99066 | 8 99109 | 8 99130 | 8·99152 | 8 99194 | 22 |
| 38 | 8 90782 | 8 90808 | 8 90834 | 8·90859 | 8 90885 | 8 99194 | 8 99237 | 8 99258 | 8·99280 | 8 99322 | 21 |
| 39 | 8 90937 | 8 90963 | 8 90989 | 8 91015 | 8 91040 | 8 99322 | 8 99365 | 8 99386 | 8·99407 | 8·99450 | 20 |
| 40 | 8 91092 | 8 91118 | 8 91143 | 8 91169 | 8 91195 | 8·99450 | 8 99492 | 8 99513 | 8·99534 | 8 99577 | 19 |
| 41 | 8 91246 | 8 91272 | 8 91298 | 8 91323 | 8 91349 | 8 99577 | 8 99619 | 8 99640 | 8·99661 | 8·99704 | 18 |
| 42 | 8 91400 | 8 91426 | 8 91451 | 8 91477 | 8 91502 | 8 99704 | 8 99746 | 8 99767 | 8·99788 | 8 99830 | 17 |
| 43 | 8 91553 | 8 91579 | 8 91604 | 8 91630 | 8 91655 | 8 99830 | 8 99872 | 8 99893 | 8·99914 | 8·99956 | 16 |
| 44 | 8 91706 | 8 91731 | 8 91757 | 8 91782 | 8 91807 | 8 99956 | 8 99998 | 9 00019 | 9·00040 | 9 00082 | 15 |
| 45 | 8 91858 | 8·91883 | 8 91909 | 8·91934 | 8·91959 | 9 00082 | 9 00123 | 9 00144 | 9·00165 | 9 00207 | 14 |
| 46 | 8 92010 | 8 92035 | 8 92060 | 8 92085 | 8 92110 | 9 00207 | 9 00249 | 9 00269 | 9·00290 | 9 00332 | 13 |
| 47 | 8 92161 | 8 92186 | 8 92211 | 8 92236 | 8 92261 | 9 00332 | 9 00373 | 9 00394 | 9·00415 | 9 00456 | 12 |
| 48 | 8 92311 | 8 92336 | 8 92361 | 8 92386 | 8 92411 | 9 00456 | 9 00498 | 9·00518 | 9·00539 | 9 00581 | 11 |
| 49 | 8 92461 | 8 92486 | 8 92511 | 8·92536 | 8 92561 | 9 00581 | 9 00622 | 9 00642 | 9·00663 | 9 00704 | 10 |
| 50 | 8 92611 | 8 92636 | 8·92660 | 8 92685 | 8 92710 | 9 00704 | 9 00746 | 9 00766 | 9·00787 | 9 00828 | 9 |
| 51 | 8 92760 | 8 92784 | 8 92809 | 8·92834 | 8·92859 | 9 00828 | 9·00869 | 9·00889 | 9·00910 | 9·00951 | 8 |
| 52 | 8 92908 | 8 92933 | 8 92957 | 8 92982 | 8 93007 | 9 00951 | 9 00992 | 9·01012 | 9·01033 | 9 01074 | 7 |
| 53 | 8 93056 | 8 93081 | 8 93105 | 8 93130 | 8 93154 | 9·01074 | 9 01115 | 9·01135 | 9·01155 | 9·01196 | 6 |
| 54 | 8 93203 | 8 93228 | 8·93253 | 8·93277 | 8 93301 | 9·01196 | 9 01237 | 9·01257 | 9·01278 | 9·01318 | 5 |
| 55 | 8 93350 | 8 93375 | 8·93399 | 8·93424 | 8·93448 | 9·01318 | 9 01359 | 9·01379 | 9·01399 | 9·01440 | 4 |
| 56 | 8 93497 | 8 93521 | 8·93546 | 8·93570 | 8 93594 | 9·01440 | 9 01480 | 9·01501 | 9·01521 | 9·01561 | 3 |
| 57 | 8 93643 | 8 93667 | 8·93691 | 8·93716 | 8·93740 | 9·01561 | 9·01602 | 9·01622 | 9·01642 | 9·01682 | 2 |
| 58 | 8·93788 | 8 93812 | 8·93837 | 8·93861 | 8 93885 | 9·01682 | 9·01723 | 9·01743 | 9·01763 | 9·01803 | 1 |
| 59 | 8·93933 | 8 93957 | 8·93981 | 8·94006 | 8·94030 | 9·01803 | 9·01843 | 9·01863 | 9·01883 | 9·01923 | 0 |
| ′ | 40″ | 30″ | 20″ | 10″ | 0″ | 60″ | 40″ | 30″ | 20″ | 0″ | ′ |
| | 85° | | | | | 84° | | | | | |

## LOG. COSINES.

## LOG. SINES, COSINES, &c.

0° | 0° = 0h 0m | 179°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | — ∞ | | Infinite. | — ∞ | | Infinite. | 0·000000 | 0 | 10·000000 | **60** | 60 |
| 1 | 4 | 6 463726 | 501717 | 3·536274 | 6·463726 | 501717 | 3 536274 | 0·000000 | 0 | 10·000000 | 56 | 59 |
| 2 | 8 | 6 764756 | 293485 | 3·235244 | 6·764756 | 293485 | 3 235244 | 0·000000 | 0 | 10·000000 | 52 | 58 |
| 3 | 12 | 6·940847 | 208231 | 3·059153 | 6·940847 | 208231 | 3·059153 | 0·000000 | 0 | 10·000000 | 48 | 57 |
| 4 | 16 | 7·065786 | 161517 | 2·934214 | 7 065786 | 161517 | 2·934214 | 0·000000 | 0 | 10·000000 | 44 | 56 |
| 5 | 20 | 7·162696 | 131968 | 2·837304 | 7 162696 | 131969 | 2 837304 | 0·000000 | 0 | 10·000000 | 40 | 55 |
| 6 | 24 | 7·241877 | 111578 | 2·758123 | 7·241878 | 111578 | 2·758122 | 0 000001 | 0 | 9 999999 | 36 | 54 |
| 7 | 28 | 7·308824 | 96653 | 2 691176 | 7·308825 | 96653 | 2 691175 | 0·000001 | 0 | 9·999999 | 32 | 53 |
| 8 | 32 | 7·366816 | 85254 | 2·633184 | 7·366817 | 85254 | 2 633183 | 0·000001 | 0 | 9 999999 | 28 | 52 |
| 9 | 36 | 7·417968 | 76262 | 2·582032 | 7·417970 | 76263 | 2·582030 | 0·000001 | 0 | 9 999999 | 24 | 51 |
| 10 | 40 | 7·463726 | 68988 | 2 536274 | 7·463727 | 68988 | 2·536273 | 0·000002 | 1 | 9 999998 | 20 | 50 |
| 11 | 44 | 7·505118 | 62981 | 2·494882 | 7·505120 | 62981 | 2·494880 | 0 000002 | 1 | 9 999998 | 16 | 49 |
| 12 | 48 | 7·542906 | 57936 | 2·457094 | 7·542909 | 57937 | 2·457091 | 0·000003 | 1 | 9 999997 | 12 | 48 |
| 13 | 52 | 7·577668 | 53641 | 2·422332 | 7·577672 | 53642 | 2·422328 | 0·000003 | 1 | 9 999997 | 8 | 47 |
| 14 | 56 | 7·609853 | 49938 | 2·390147 | 7·609857 | 49939 | 2·390143 | 0·000004 | 1 | 9 999996 | 4 | 46 |
| 15 | **1** | 7·639816 | 46714 | 2·360184 | 7 639820 | 46715 | 2·360180 | 0 000004 | 1 | 9 999996 | **59** | 45 |
| 16 | 4 | 7·667845 | 43881 | 2·332155 | 7·667849 | 43882 | 2·332151 | 0·000005 | 1 | 9 999995 | 56 | 44 |
| 17 | 8 | 7·694173 | 41372 | 2·305827 | 7·694179 | 41373 | 2·305821 | 0·000005 | 1 | 9 999995 | 52 | 43 |
| 18 | 12 | 7·718997 | 39135 | 2·281003 | 7·719003 | 39136 | 2·280997 | 0·000006 | 1 | 9 999994 | 48 | 42 |
| 19 | 16 | 7·742478 | 37127 | 2·257522 | 7·742484 | 37128 | 2·257516 | 0 000007 | 1 | 9 999993 | 44 | 41 |
| 20 | 20 | 7·764754 | 35315 | 2·235246 | 7·764761 | 35313 | 2·235239 | 0 000007 | 1 | 9 999993 | 40 | 40 |
| 21 | 24 | 7·785943 | 33672 | 2·214057 | 7·785951 | 33673 | 2 214049 | 0 000008 | 1 | 9 999992 | 36 | 39 |
| 22 | 28 | 7·806146 | 32175 | 2·193854 | 7·806155 | 32176 | 2·193845 | 0·000009 | 1 | 9 999991 | 32 | 38 |
| 23 | 32 | 7·825451 | 30805 | 2·174549 | 7·825460 | 30807 | 2·174540 | 0·000010 | 1 | 9 999990 | 28 | 37 |
| 24 | 36 | 7·843934 | 29547 | 2·156066 | 7·843944 | 29549 | 2·156056 | 0 000011 | 1 | 9 999989 | 24 | 36 |
| 25 | 40 | 7·861662 | 28388 | 2·138338 | 7·861674 | 28390 | 2·138326 | 0·000011 | 2 | 9 999989 | 20 | 35 |
| 26 | 44 | 7·878695 | 27317 | 2·121305 | 7·878708 | 27318 | 2·121292 | 0 000012 | 2 | 9 999988 | 16 | 34 |
| 27 | 48 | 7·895085 | 26323 | 2·104915 | 7·895099 | 26325 | 2·104901 | 0·000013 | 2 | 9 999987 | 12 | 33 |
| 28 | 52 | 7·910879 | 25399 | 2·089121 | 7·910894 | 25401 | 2·089106 | 0·000014 | 2 | 9 999986 | 8 | 32 |
| 29 | 56 | 7·926119 | 24538 | 2·073881 | 7·926134 | 24540 | 2·073866 | 0·000015 | 2 | 9 999985 | 4 | 31 |
| 30 | **2** | 7·940842 | 23733 | 2·059158 | 7·940858 | 23735 | 2·059142 | 0·000017 | 2 | 9 999983 | **58** | 30 |
| 31 | 4 | 7·955082 | 22980 | 2·044918 | 7·955100 | 22982 | 2 044900 | 0·000018 | 2 | 9 999982 | 56 | 29 |
| 32 | 8 | 7·968870 | 22273 | 2·031130 | 7·968889 | 22275 | 2·031111 | 0·000019 | 2 | 9 999981 | 52 | 28 |
| 33 | 12 | 7·982233 | 21608 | 2·017767 | 7·982253 | 21610 | 2·017747 | 0·000020 | 2 | 9 999980 | 48 | 27 |
| 34 | 16 | 7·995198 | 20981 | 2·004802 | 7·995219 | 20983 | 2·004781 | 0·000021 | 2 | 9 999979 | 44 | 26 |
| 35 | 20 | 8·007787 | 20390 | 1·992213 | 8·007809 | 20392 | 1·992191 | 0·000023 | 2 | 9 999977 | 40 | 25 |
| 36 | 24 | 8·020021 | 19831 | 1·979979 | 8·020044 | 19833 | 1·979956 | 0 000024 | 2 | 9 999976 | 36 | 24 |
| 37 | 28 | 8·031919 | 19302 | 1·968081 | 8·031945 | 19305 | 1·968055 | 0·000025 | 2 | 9 999975 | 32 | 23 |
| 38 | 32 | 8·043501 | 18801 | 1·956499 | 8·043527 | 18803 | 1·956473 | 0·000027 | 2 | 9 999973 | 28 | 22 |
| 39 | 36 | 8·054781 | 18325 | 1·945219 | 8·054809 | 18327 | 1·945191 | 0·000028 | 2 | 9 999972 | 24 | 21 |
| 40 | 40 | 8·065776 | 17872 | 1·934224 | 8·065806 | 17875 | 1·934194 | 0·000029 | 2 | 9 999971 | 20 | 20 |
| 41 | 44 | 8·076500 | 17441 | 1·923500 | 8·076531 | 17444 | 1·923469 | 0·000031 | 2 | 9 999969 | 16 | 19 |
| 42 | 48 | 8·086965 | 17031 | 1·913035 | 8·086997 | 17034 | 1·913003 | 0·000032 | 3 | 9 999968 | 12 | 18 |
| 43 | 52 | 8·097183 | 16639 | 1·902817 | 8·097217 | 16642 | 1·902783 | 0·000034 | 3 | 9 999966 | 8 | 17 |
| 44 | 56 | 8·107167 | 16265 | 1·892833 | 8·107203 | 16268 | 1·892797 | 0·000036 | 3 | 9 999964 | 4 | 16 |
| 45 | **3** | 8·116926 | 15908 | 1·883074 | 8·116963 | 15911 | 1·883037 | 0·000037 | 3 | 9 999963 | **57** | 15 |
| 46 | 4 | 8·126471 | 15566 | 1·873529 | 8·126510 | 15568 | 1·873490 | 0·000039 | 3 | 9 999961 | 56 | 14 |
| 47 | 8 | 8·135810 | 15238 | 1·864190 | 8·135851 | 15241 | 1·864149 | 0·000041 | 3 | 9 999959 | 52 | 13 |
| 48 | 12 | 8·144953 | 14924 | 1·855047 | 8·144996 | 14927 | 1·855004 | 0·000042 | 3 | 9 999958 | 48 | 12 |
| 49 | 16 | 8·153907 | 14622 | 1·846093 | 8·153952 | 14625 | 1·846048 | 0·000044 | 3 | 9 999956 | 44 | 11 |
| 50 | 20 | 8·162681 | 14333 | 1·837319 | 8·162727 | 14336 | 1·837273 | 0·000046 | 3 | 9 999954 | 40 | 10 |
| 51 | 24 | 8·171280 | 14054 | 1·828720 | 8·171328 | 14057 | 1·828672 | 0·000048 | 3 | 9 999952 | 36 | 9 |
| 52 | 28 | 8·179713 | 13786 | 1·820287 | 8·179763 | 13790 | 1·820237 | 0·000050 | 3 | 9 999950 | 32 | 8 |
| 53 | 32 | 8·187985 | 13529 | 1·812015 | 8·188036 | 13532 | 1·811964 | 0·000052 | 3 | 9 999948 | 28 | 7 |
| 54 | 36 | 8·196102 | 13280 | 1·803898 | 8·196156 | 13284 | 1·803844 | 0·000054 | 3 | 9 999946 | 24 | 6 |
| 55 | 40 | 8·204070 | 13041 | 1·795930 | 8·204126 | 13044 | 1·795874 | 0·000056 | 3 | 9 999944 | 20 | 5 |
| 56 | 44 | 8·211895 | 12810 | 1·788105 | 8·211953 | 12814 | 1·788047 | 0 000058 | 3 | 9 999942 | 16 | 4 |
| 57 | 48 | 8·219581 | 12587 | 1·780419 | 8·219641 | 12591 | 1·780359 | 0·000060 | 3 | 9 999940 | 12 | 3 |
| 58 | 52 | 8·227134 | 12372 | 1·772866 | 8·227195 | 12376 | 1·772805 | 0·000062 | 3 | 9 999938 | 8 | 2 |
| 59 | 56 | 8·234557 | 12164 | 1·765443 | 8·234621 | 12168 | 1·765379 | 0·000064 | 3 | 9 999936 | 4 | 1 |
| 60 | **4** | 8·241855 | | 1·758145 | 8·241921 | | 1·758079 | 0·000066 | | 9 999934 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

90° | 89° = 5h 56m | 89°

## LOG. SINES, COSINES, &c.

1° | $1° = 0^h\ 4^m$ | 178°

| ′ | M. / S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8·241855 | 11963 | 1·758145 | 8·241921 | 11967 | 1·758079 | 0·000066 | 4 | 9 999934 | **56** | 60 |
| 1 | 4 | 8·249033 | 11768 | 1·750967 | 8·249102 | 11772 | 1·750898 | 0·000068 | 4 | 9 999932 | 56 | 59 |
| 2 | 8 | 8·256094 | 11580 | 1·743906 | 8·256165 | 11584 | 1·743835 | 0·000071 | 4 | 9 999929 | 52 | 58 |
| 3 | 12 | 8·263042 | 11398 | 1·736958 | 8·263115 | 11402 | 1·736885 | 0·000073 | 4 | 9 999927 | 48 | 57 |
| 4 | 16 | 8·269881 | 11221 | 1·730119 | 8·269956 | 11225 | 1·730044 | 0·000075 | 4 | 9 999925 | 44 | 56 |
| 5 | 20 | 8·276614 | 11050 | 1·723386 | 8·276691 | 11054 | 1·723309 | 0·000078 | 4 | 9 999922 | 40 | 55 |
| 6 | 24 | 8·283243 | 10883 | 1·716757 | 8·283323 | 10887 | 1·716677 | 0·000080 | 4 | 9 999920 | 36 | 54 |
| 7 | 28 | 8·289773 | 10723 | 1·710227 | 8·289856 | 10726 | 1·710144 | 0·000082 | 4 | 9 999918 | 32 | 53 |
| 8 | 32 | 8·296207 | 10565 | 1·703793 | 8·296292 | 10570 | 1·703708 | 0·000085 | 4 | 9 999915 | 28 | 52 |
| 9 | 36 | 8·302546 | 10413 | 1·697454 | 8·302634 | 10418 | 1·697366 | 0·000087 | 4 | 9 999913 | 24 | 51 |
| 10 | 40 | 8·308794 | 10266 | 1·691206 | 8·308884 | 10270 | 1·691116 | 0·000090 | 4 | 9 999910 | 20 | 50 |
| 11 | 44 | 8·314954 | 10122 | 1·685046 | 8·315046 | 10126 | 1·684954 | 0·000093 | 4 | 9 999907 | 16 | 49 |
| 12 | 48 | 8·321027 | 9982 | 1·678973 | 8·321122 | 9987 | 1·678878 | 0·000095 | 4 | 9 999905 | 12 | 48 |
| 13 | 52 | 8·327016 | 9847 | 1·672984 | 8·327114 | 9851 | 1·672886 | 0·000098 | 4 | 9 999902 | 8 | 47 |
| 14 | 56 | 8·332924 | 9714 | 1·667076 | 8·333025 | 9719 | 1·666975 | 0·000101 | 5 | 9 999899 | 4 | 46 |
| 15 | **5** | 8·338753 | 9586 | 1·661247 | 8·338856 | 9590 | 1·661144 | 0·000103 | 5 | 9 999897 | **55** | 45 |
| 16 | 4 | 8·344504 | 9460 | 1·655496 | 8·344610 | 9465 | 1·655390 | 0·000106 | 5 | 9 999894 | 56 | 44 |
| 17 | 8 | 8·350181 | 9338 | 1·649819 | 8·350289 | 9343 | 1·649711 | 0·000109 | 5 | 9 999891 | 52 | 43 |
| 18 | 12 | 8·355783 | 9219 | 1·644217 | 8·355895 | 9224 | 1·644105 | 0·000112 | 5 | 9 999888 | 48 | 42 |
| 19 | 16 | 8·361315 | 9103 | 1·638685 | 8·361430 | 9108 | 1·638570 | 0·000115 | 5 | 9 999885 | 44 | 41 |
| 20 | 20 | 8·366777 | 8990 | 1·633223 | 8·366895 | 8995 | 1·633105 | 0·000118 | 5 | 9 999882 | 40 | 40 |
| 21 | 24 | 8·372171 | 8880 | 1·627829 | 8·372292 | 8885 | 1·627708 | 0·000121 | 5 | 9 999879 | 36 | 39 |
| 22 | 28 | 8·377499 | 8772 | 1·622501 | 8·377622 | 8777 | 1·622378 | 0·000124 | 5 | 9 999876 | 32 | 38 |
| 23 | 32 | 8·382762 | 8667 | 1·617238 | 8·382889 | 8672 | 1·617111 | 0·000127 | 5 | 9 999873 | 28 | 37 |
| 24 | 36 | 8·387962 | 8564 | 1·612038 | 8·388092 | 8570 | 1·611908 | 0·000130 | 5 | 9 999870 | 24 | 36 |
| 25 | 40 | 8·393101 | 8464 | 1·606899 | 8·393234 | 8470 | 1·606766 | 0·000133 | 5 | 9 999867 | 20 | 35 |
| 26 | 44 | 8·398179 | 8366 | 1·601821 | 8·398315 | 8371 | 1·601685 | 0·000136 | 5 | 9 999864 | 16 | 34 |
| 27 | 48 | 8·403199 | 8271 | 1·596801 | 8·403338 | 8276 | 1·596662 | 0·000139 | 5 | 9 999861 | 12 | 33 |
| 28 | 52 | 8·408161 | 8177 | 1·591839 | 8·408304 | 8182 | 1·591696 | 0·000142 | 5 | 9 999858 | 8 | 32 |
| 29 | 56 | 8·413068 | 8086 | 1·586932 | 8·413213 | 8091 | 1·586787 | 0·000146 | 5 | 9 999854 | 4 | 31 |
| 30 | **6** | 8·417919 | 7996 | 1·582081 | 8·418068 | 8002 | 1·581932 | 0·000149 | 6 | 9 999851 | **54** | 30 |
| 31 | 4 | 8·422717 | 7909 | 1·577283 | 8·422869 | 7914 | 1·577131 | 0·000152 | 6 | 9 999848 | 56 | 29 |
| 32 | 8 | 8·427462 | 7823 | 1·572538 | 8·427618 | 7828 | 1·572382 | 0·000156 | 6 | 9 999844 | 52 | 28 |
| 33 | 12 | 8·432156 | 7740 | 1·567844 | 8·432315 | 7745 | 1·567685 | 0·000159 | 6 | 9 999841 | 48 | 27 |
| 34 | 16 | 8·436800 | 7657 | 1·563200 | 8·436962 | 7663 | 1·563038 | 0·000162 | 6 | 9 999838 | 44 | 26 |
| 35 | 20 | 8·441394 | 7577 | 1·558606 | 8·441560 | 7583 | 1·558440 | 0·000166 | 6 | 9 999834 | 40 | 25 |
| 36 | 24 | 8·445941 | 7499 | 1·554059 | 8·446110 | 7505 | 1·553890 | 0·000169 | 6 | 9 999831 | 36 | 24 |
| 37 | 28 | 8·450440 | 7422 | 1·549560 | 8·450613 | 7428 | 1·549387 | 0·000173 | 6 | 9 999827 | 32 | 23 |
| 38 | 32 | 8·454893 | 7346 | 1·545107 | 8·455070 | 7352 | 1·544930 | 0·000176 | 6 | 9 999824 | 28 | 22 |
| 39 | 36 | 8·459301 | 7273 | 1·540699 | 8·459481 | 7279 | 1·540519 | 0·000180 | 6 | 9 999820 | 24 | 21 |
| 40 | 40 | 8·463665 | 7200 | 1·536335 | 8·463849 | 7206 | 1·536151 | 0·000184 | 6 | 9 999816 | 20 | 20 |
| 41 | 44 | 8·467985 | 7129 | 1·532015 | 8·468172 | 7135 | 1·531828 | 0·000187 | 6 | 9 999813 | 16 | 19 |
| 42 | 48 | 8·472263 | 7060 | 1·527737 | 8·472454 | 7066 | 1·527546 | 0·000191 | 6 | 9 999809 | 12 | 18 |
| 43 | 52 | 8·476498 | 6991 | 1·523502 | 8·476693 | 6998 | 1·523307 | 0·000195 | 6 | 9 999805 | 8 | 17 |
| 44 | 56 | 8·480693 | 6924 | 1·519307 | 8·480892 | 6931 | 1·519108 | 0·000199 | 6 | 9 999801 | 4 | 16 |
| 45 | **7** | 8·484848 | 6859 | 1·515152 | 8·485050 | 6865 | 1·514950 | 0·000203 | 7 | 9 999797 | **53** | 15 |
| 46 | 4 | 8·488963 | 6794 | 1·511037 | 8·489170 | 6801 | 1·510830 | 0·000206 | 7 | 9 999794 | 56 | 14 |
| 47 | 8 | 8·493040 | 6731 | 1·506960 | 8·493250 | 6738 | 1·506750 | 0·000210 | 7 | 9 999790 | 52 | 13 |
| 48 | 12 | 8·497078 | 6669 | 1·502922 | 8·497293 | 6676 | 1·502707 | 0·000214 | 7 | 9 999786 | 48 | 12 |
| 49 | 16 | 8·501080 | 6608 | 1·498920 | 8·501298 | 6615 | 1·498702 | 0·000218 | 7 | 9 999782 | 44 | 11 |
| 50 | 20 | 8·505045 | 6548 | 1·494955 | 8·505267 | 6555 | 1·494733 | 0·000222 | 7 | 9 999778 | 40 | 10 |
| 51 | 24 | 8·508974 | 6489 | 1·491026 | 8·509200 | 6496 | 1·490800 | 0·000226 | 7 | 9 999774 | 36 | 9 |
| 52 | 28 | 8·512867 | 6432 | 1·487133 | 8·513098 | 6439 | 1·486902 | 0·000231 | 7 | 9 999769 | 32 | 8 |
| 53 | 32 | 8·516726 | 6375 | 1·483274 | 8·516961 | 6382 | 1·483039 | 0·000235 | 7 | 9 999765 | 28 | 7 |
| 54 | 36 | 8·520551 | 6319 | 1·479449 | 8·520790 | 6326 | 1·479210 | 0·000239 | 7 | 9 999761 | 24 | 6 |
| 55 | 40 | 8·524343 | 6264 | 1·475657 | 8·524586 | 6272 | 1·475414 | 0·000243 | 7 | 9 999757 | 20 | 5 |
| 56 | 44 | 8·528102 | 6211 | 1·471898 | 8·528349 | 6218 | 1·471651 | 0·000247 | 7 | 9 999753 | 16 | 4 |
| 57 | 48 | 8·531828 | 6158 | 1·468172 | 8·532080 | 6165 | 1·467920 | 0·000252 | 7 | 9 999748 | 12 | 3 |
| 58 | 52 | 8·535523 | 6106 | 1·464477 | 8·535779 | 6113 | 1·464221 | 0·000256 | 7 | 9 999744 | 8 | 2 |
| 59 | 56 | 8·539186 | 6055 | 1·460814 | 8·539447 | 6062 | 1·460553 | 0·000260 | 7 | 9 999740 | 4 | 1 |
| 60 | **8** | 8·542819 | | 1·457181 | 8·543084 | | 1·456916 | 0·000265 | | 9 999735 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

91° | $88° = 5^h\ 52^m$ | 88°

## LOG. SINES, COSINES, &c.

2° $= 0^h\ 8^m$ 177°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8·542819 | 6004 | 1·457181 | 8·543084 | 6012 | 1·456916 | 0·000265 | 7 | 9·999735 | **52** | 60 |
| 1 | 4 | 8·546422 | 5955 | 1·453578 | 8·546691 | 5962 | 1·453309 | 0·000269 | 7 | 9·999731 | 56 | 59 |
| 2 | 8 | 8·549995 | 5906 | 1·450005 | 8·550268 | 5914 | 1·449732 | 0·000274 | 7 | 9·999726 | 52 | 58 |
| 3 | 12 | 8·553539 | 5858 | 1·446461 | 8·553817 | 5866 | 1·446183 | 0·000278 | 8 | 9·999722 | 48 | 57 |
| 4 | 16 | 8·557054 | 5811 | 1·442946 | 8·557336 | 5819 | 1·442664 | 0·000283 | 8 | 9·999717 | 44 | 56 |
| 5 | 20 | 8·560540 | 5765 | 1·439460 | 8·560828 | 5773 | 1·439172 | 0·000287 | 8 | 9·999713 | 40 | 55 |
| 6 | 24 | 8·563999 | 5719 | 1·436001 | 8·564291 | 5727 | 1·435709 | 0·000292 | 8 | 9·999708 | 36 | 54 |
| 7 | 28 | 8·567431 | 5674 | 1·432569 | 8·567727 | 5682 | 1·432273 | 0·000296 | 8 | 9·999704 | 32 | 53 |
| 8 | 32 | 8·570836 | 5630 | 1·429164 | 8·571137 | 5638 | 1·428863 | 0·000301 | 8 | 9·999699 | 28 | 52 |
| 9 | 36 | 8·574214 | 5587 | 1·425786 | 8·574520 | 5595 | 1·425480 | 0·000306 | 8 | 9·999694 | 24 | 51 |
| 10 | 40 | 8·577566 | 5544 | 1·422434 | 8·577877 | 5552 | 1·422123 | 0·000311 | 8 | 9·999689 | 20 | 50 |
| 11 | 44 | 8·580892 | 5502 | 1·419108 | 8·581208 | 5510 | 1·418792 | 0·000315 | 8 | 9·999685 | 16 | 49 |
| 12 | 48 | 8·584193 | 5460 | 1·415807 | 8·584514 | 5468 | 1·415486 | 0·000320 | 8 | 9·999680 | 12 | 48 |
| 13 | 52 | 8·587469 | 5419 | 1·412531 | 8·587795 | 5427 | 1·412205 | 0·000325 | 8 | 9·999675 | 8 | 47 |
| 14 | 56 | 8·590721 | 5379 | 1·409279 | 8·591051 | 5387 | 1·408949 | 0·000330 | 8 | 9·999670 | 4 | 46 |
| 15 | **9** | 8·593948 | 5339 | 1·406052 | 8·594283 | 5347 | 1·405717 | 0·000335 | 8 | 9·999665 | **51** | 45 |
| 16 | 4 | 8·597152 | 5300 | 1·402848 | 8·597492 | 5308 | 1·402508 | 0·000340 | 8 | 9·999660 | 56 | 44 |
| 17 | 8 | 8·600332 | 5261 | 1·399668 | 8·600677 | 5270 | 1·399323 | 0·000345 | 8 | 9·999655 | 52 | 43 |
| 18 | 12 | 8·603489 | 5223 | 1·396511 | 8·603839 | 5232 | 1·396161 | 0·000350 | 8 | 9·999650 | 48 | 42 |
| 19 | 16 | 8·606623 | 5186 | 1·393377 | 8·606978 | 5194 | 1·393022 | 0·000355 | 9 | 9·999645 | 44 | 41 |
| 20 | 20 | 8·609734 | 5149 | 1·390266 | 8·610094 | 5158 | 1·389906 | 0·000360 | 9 | 9·999640 | 40 | 40 |
| 21 | 24 | 8·612823 | 5112 | 1·387177 | 8·613189 | 5121 | 1·386811 | 0·000365 | 9 | 9·999635 | 36 | 39 |
| 22 | 28 | 8·615891 | 5076 | 1·384109 | 8·616262 | 5085 | 1·383738 | 0·000371 | 9 | 9·999629 | 32 | 38 |
| 23 | 32 | 8·618937 | 5041 | 1·381063 | 8·619313 | 5050 | 1·380687 | 0·000376 | 9 | 9·999624 | 28 | 37 |
| 24 | 36 | 8·621962 | 5006 | 1·378038 | 8·622343 | 5015 | 1·377657 | 0·000381 | 9 | 9·999619 | 24 | 36 |
| 25 | 40 | 8·624965 | 4972 | 1·375035 | 8·625352 | 4981 | 1·374648 | 0·000386 | 9 | 9·999614 | 20 | 35 |
| 26 | 44 | 8·627948 | 4938 | 1·372052 | 8·628340 | 4947 | 1·371660 | 0·000392 | 9 | 9·999608 | 16 | 34 |
| 27 | 48 | 8·630911 | 4904 | 1·369089 | 8·631308 | 4913 | 1·368692 | 0·000397 | 9 | 9·999603 | 12 | 33 |
| 28 | 52 | 8·633854 | 4871 | 1·366146 | 8·634256 | 4880 | 1·365744 | 0·000403 | 9 | 9·999597 | 8 | 32 |
| 29 | 56 | 8·636776 | 4839 | 1·363224 | 8·637184 | 4848 | 1·362816 | 0·000408 | 9 | 9·999592 | 4 | 31 |
| 30 | **10** | 8·639680 | 4806 | 1·360320 | 8·640093 | 4816 | 1·359907 | 0·000414 | 9 | 9·999586 | **50** | 30 |
| 31 | 4 | 8·642563 | 4776 | 1·357437 | 8·642982 | 4786 | 1·357018 | 0·000419 | 9 | 9·999581 | 56 | 29 |
| 32 | 8 | 8·645428 | 4743 | 1·354572 | 8·645853 | 4753 | 1·354147 | 0·000425 | 9 | 9·999575 | 52 | 28 |
| 33 | 12 | 8·648274 | 4712 | 1·351726 | 8·648704 | 4722 | 1·351296 | 0·000430 | 9 | 9·999570 | 48 | 27 |
| 34 | 16 | 8·651102 | 4682 | 1·348898 | 8·651537 | 4691 | 1·348463 | 0·000436 | 9 | 9·999564 | 44 | 26 |
| 35 | 20 | 8·653911 | 4652 | 1·346089 | 8·654352 | 4661 | 1·345648 | 0·000442 | 9 | 9·999558 | 40 | 25 |
| 36 | 24 | 8·656702 | 4622 | 1·343298 | 8·657149 | 4631 | 1·342851 | 0·000447 | 10 | 9·999553 | 36 | 24 |
| 37 | 28 | 8·659475 | 4592 | 1·340525 | 8·659928 | 4602 | 1·340072 | 0·000453 | 10 | 9·999547 | 32 | 23 |
| 38 | 32 | 8·662230 | 4563 | 1·337770 | 8·662689 | 4573 | 1·337311 | 0·000459 | 10 | 9·999541 | 28 | 22 |
| 39 | 36 | 8·664968 | 4535 | 1·335032 | 8·665433 | 4544 | 1·334567 | 0·000465 | 10 | 9·999535 | 24 | 21 |
| 40 | 40 | 8·667689 | 4506 | 1·332311 | 8·668160 | 4517 | 1·331840 | 0·000471 | 10 | 9·999529 | 20 | 20 |
| 41 | 44 | 8·670393 | 4479 | 1·329607 | 8·670870 | 4488 | 1·329130 | 0·000476 | 10 | 9·999524 | 16 | 19 |
| 42 | 48 | 8·673080 | 4451 | 1·326920 | 8·673563 | 4461 | 1·326437 | 0·000482 | 10 | 9·999518 | 12 | 18 |
| 43 | 52 | 8·675751 | 4424 | 1·324249 | 8·676239 | 4434 | 1·323761 | 0·000488 | 10 | 9·999512 | 8 | 17 |
| 44 | 56 | 8·678405 | 4397 | 1·321595 | 8·678900 | 4407 | 1·321100 | 0·000494 | 10 | 9·999506 | 4 | 16 |
| 45 | **11** | 8·681043 | 4370 | 1·318957 | 8·681544 | 4380 | 1·318456 | 0·000500 | 10 | 9·999500 | **49** | 15 |
| 46 | 4 | 8·683665 | 4344 | 1·316335 | 8·684172 | 4354 | 1·315828 | 0·000507 | 10 | 9·999493 | 56 | 14 |
| 47 | 8 | 8·686272 | 4318 | 1·313728 | 8·686784 | 4328 | 1·313216 | 0·000513 | 10 | 9·999487 | 52 | 13 |
| 48 | 12 | 8·688863 | 4292 | 1·311137 | 8·689381 | 4303 | 1·310619 | 0·000519 | 10 | 9·999481 | 48 | 12 |
| 49 | 16 | 8·691438 | 4267 | 1·308562 | 8·691963 | 4277 | 1·308037 | 0·000525 | 10 | 9·999475 | 44 | 11 |
| 50 | 20 | 8·693998 | 4242 | 1·306002 | 8·694529 | 4252 | 1·305471 | 0·000531 | 10 | 9·999469 | 40 | 10 |
| 51 | 24 | 8·696543 | 4217 | 1·303457 | 8·697081 | 4228 | 1·302919 | 0·000537 | 11 | 9·999463 | 36 | 9 |
| 52 | 28 | 8·699073 | 4192 | 1·300927 | 8·699617 | 4203 | 1·300383 | 0·000544 | 11 | 9·999456 | 32 | 8 |
| 53 | 32 | 8·701589 | 4168 | 1·298411 | 8·702139 | 4179 | 1·297861 | 0·000550 | 11 | 9·999450 | 28 | 7 |
| 54 | 36 | 8·704090 | 4144 | 1·295910 | 8·704646 | 4155 | 1·295354 | 0·000557 | 11 | 9·999443 | 24 | 6 |
| 55 | 40 | 8·706577 | 4121 | 1·293423 | 8·707140 | 4132 | 1·292860 | 0·000563 | 11 | 9·999437 | 20 | 5 |
| 56 | 44 | 8·709049 | 4097 | 1·290951 | 8·709618 | 4108 | 1·290382 | 0·000569 | 11 | 9·999431 | 16 | 4 |
| 57 | 48 | 8·711507 | 4074 | 1·288493 | 8·712083 | 4085 | 1·287917 | 0·000576 | 11 | 9·999424 | 12 | 3 |
| 58 | 52 | 8·713952 | 4051 | 1·286048 | 8·714534 | 4062 | 1·285466 | 0·000582 | 11 | 9·999418 | 8 | 2 |
| 59 | 56 | 8·716383 | 4029 | 1·283617 | 8·716972 | 4040 | 1·283028 | 0·000589 | 11 | 9·999411 | 4 | 1 |
| 60 | **12** | 8·718800 | | 1·281200 | 8·719396 | | 1·280604 | 0·000596 | 11 | 9·999404 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

92° $87° = 5^h\ 48^m$ 87°

## LOG. SINES, COSINES, &c.

3° $3° = 0^h\ 12^m$ 176°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8·718800 | 4006 | 1·281200 | 8·719396 | 4017 | 1·280604 | 0·000596 | 11 | 9·999404 | **48** | 60 |
| 1 | 4 | 8·721204 | 3984 | 1·278796 | 8·721806 | 3995 | 1·278194 | 0·000602 | 11 | 9·999398 | 56 | 59 |
| 2 | 8 | 8·723595 | 3962 | 1·276405 | 8·724204 | 3974 | 1·275796 | 0·000609 | 11 | 9·999391 | 52 | 58 |
| 3 | 12 | 8·725972 | 3941 | 1·274028 | 8·726588 | 3952 | 1·273412 | 0·000616 | 11 | 9·999384 | 48 | 57 |
| 4 | 16 | 8·728337 | 3919 | 1·271663 | 8·728959 | 3930 | 1·271041 | 0·000622 | 11 | 9·999378 | 44 | 56 |
| 5 | 20 | 8·730688 | 3898 | 1·269312 | 8·731317 | 3909 | 1·268683 | 0·000629 | 11 | 9·999371 | 40 | 55 |
| 6 | 24 | 8·733027 | 3877 | 1·266973 | 8·733663 | 3889 | 1·266337 | 0·000636 | 12 | 9·999364 | 36 | 54 |
| 7 | 28 | 8·735354 | 3857 | 1·264646 | 8·735996 | 3868 | 1·264004 | 0·000643 | 12 | 9·999357 | 32 | 53 |
| 8 | 32 | 8·737667 | 3836 | 1·262333 | 8·738317 | 3848 | 1·261683 | 0·000650 | 12 | 9·999350 | 28 | 52 |
| 9 | 36 | 8·739969 | 3816 | 1·260031 | 8·740626 | 3827 | 1·259374 | 0·000657 | 12 | 9·999343 | 24 | 51 |
| 10 | 40 | 8·742259 | 3796 | 1·257741 | 8·742922 | 3807 | 1·257078 | 0·000664 | 12 | 9·999336 | 20 | 50 |
| 11 | 44 | 8·744536 | 3776 | 1·255464 | 8·745207 | 3787 | 1·254793 | 0·000671 | 12 | 9·999329 | 16 | 49 |
| 12 | 48 | 8·746802 | 3756 | 1·253198 | 8·747479 | 3768 | 1·252521 | 0·000678 | 12 | 9·999322 | 12 | 48 |
| 13 | 52 | 8·749055 | 3737 | 1·250945 | 8·749740 | 3749 | 1·250260 | 0·000685 | 12 | 9·999315 | 8 | 47 |
| 14 | 56 | 8·751297 | 3717 | 1·248703 | 8·751989 | 3729 | 1·248011 | 0·000692 | 12 | 9·999308 | 4 | 46 |
| 15 | **13** | 8·753528 | 3698 | 1·246472 | 8·754227 | 3710 | 1·245773 | 0·000699 | 12 | 9·999301 | **47** | 45 |
| 16 | 4 | 8·755747 | 3678 | 1·244253 | 8·756453 | 3692 | 1·243547 | 0·000706 | 12 | 9·999294 | 56 | 44 |
| 17 | 8 | 8·757955 | 3661 | 1·242045 | 8·758668 | 3673 | 1·241332 | 0·000713 | 12 | 9·999287 | 52 | 43 |
| 18 | 12 | 8·760151 | 3642 | 1·239849 | 8·760872 | 3655 | 1·239128 | 0·000721 | 12 | 9·999279 | 48 | 42 |
| 19 | 16 | 8·762337 | 3624 | 1·237663 | 8·763065 | 3636 | 1·236935 | 0·000728 | 12 | 9·999272 | 44 | 41 |
| 20 | 20 | 8·764511 | 3606 | 1·235489 | 8·765246 | 3618 | 1·234754 | 0·000735 | 12 | 9·999265 | 40 | 40 |
| 21 | 24 | 8·766675 | 3588 | 1·233325 | 8·767417 | 3600 | 1·232583 | 0·000743 | 12 | 9·999257 | 36 | 39 |
| 22 | 28 | 8·768828 | 3570 | 1·231172 | 8·769578 | 3583 | 1·230422 | 0·000750 | 13 | 9·999250 | 32 | 38 |
| 23 | 32 | 8·770970 | 3553 | 1·229030 | 8·771727 | 3565 | 1·228273 | 0·000758 | 13 | 9·999242 | 28 | 37 |
| 24 | 36 | 8·773101 | 3535 | 1·226899 | 8·773866 | 3548 | 1·226134 | 0·000765 | 13 | 9·999235 | 24 | 36 |
| 25 | 40 | 8·775223 | 3518 | 1·224777 | 8·775995 | 3531 | 1·224005 | 0·000773 | 13 | 9·999227 | 20 | 35 |
| 26 | 44 | 8·777333 | 3501 | 1·222667 | 8·778114 | 3514 | 1·221886 | 0·000780 | 13 | 9·999220 | 16 | 34 |
| 27 | 48 | 8·779434 | 3484 | 1·220566 | 8·780222 | 3497 | 1·219778 | 0·000788 | 13 | 9·999212 | 12 | 33 |
| 28 | 52 | 8·781524 | 3467 | 1·218476 | 8·782320 | 3480 | 1·217680 | 0·000795 | 13 | 9·999205 | 8 | 32 |
| 29 | 56 | 8·783605 | 3451 | 1·216395 | 8·784408 | 3464 | 1·215592 | 0·000803 | 13 | 9·999197 | 4 | 31 |
| 30 | **14** | 8·785675 | 3434 | 1·214325 | 8·786486 | 3447 | 1·213514 | 0·000811 | 13 | 9·999189 | **46** | 30 |
| 31 | 4 | 8·787736 | 3418 | 1·212264 | 8·788554 | 3431 | 1·211446 | 0·000819 | 13 | 9·999181 | 56 | 29 |
| 32 | 8 | 8·789787 | 3402 | 1·210213 | 8·790613 | 3415 | 1·209387 | 0·000826 | 13 | 9·999174 | 52 | 28 |
| 33 | 12 | 8·791828 | 3386 | 1·208172 | 8·792662 | 3399 | 1·207338 | 0·000834 | 13 | 9·999166 | 48 | 27 |
| 34 | 16 | 8·793859 | 3370 | 1·206141 | 8·794701 | 3383 | 1·205299 | 0·000842 | 13 | 9·999158 | 44 | 26 |
| 35 | 20 | 8·795881 | 3354 | 1·204119 | 8·796731 | 3368 | 1·203269 | 0·000850 | 13 | 9·999150 | 40 | 25 |
| 36 | 24 | 8·797894 | 3339 | 1·202106 | 8·798752 | 3352 | 1·201248 | 0·000858 | 13 | 9·999142 | 36 | 24 |
| 37 | 28 | 8·799897 | 3323 | 1·200103 | 8·800763 | 3337 | 1·199237 | 0·000866 | 13 | 9·999134 | 32 | 23 |
| 38 | 32 | 8·801892 | 3308 | 1·198108 | 8·802765 | 3322 | 1·197235 | 0·000874 | 13 | 9·999126 | 28 | 22 |
| 39 | 36 | 8·803876 | 3293 | 1·196124 | 8·804758 | 3307 | 1·195242 | 0·000882 | 13 | 9·999118 | 24 | 21 |
| 40 | 40 | 8·805852 | 3278 | 1·194148 | 8·806742 | 3292 | 1·193258 | 0·000890 | 13 | 9·999110 | 20 | 20 |
| 41 | 44 | 8·807819 | 3263 | 1·192181 | 8·808717 | 3277 | 1·191283 | 0·000898 | 13 | 9·999102 | 16 | 19 |
| 42 | 48 | 8·809777 | 3249 | 1·190223 | 8·810683 | 3262 | 1·189317 | 0·000906 | 14 | 9·999094 | 12 | 18 |
| 43 | 52 | 8·811726 | 3234 | 1·188274 | 8·812641 | 3248 | 1·187359 | 0·000914 | 14 | 9·999086 | 8 | 17 |
| 44 | 56 | 8·813667 | 3219 | 1·186333 | 8·814589 | 3233 | 1·185411 | 0·000923 | 14 | 9·999077 | 4 | 16 |
| 45 | **15** | 8·815599 | 3205 | 1·184401 | 8·816529 | 3219 | 1·183471 | 0·000931 | 14 | 9·999069 | **45** | 15 |
| 46 | 4 | 8·817522 | 3191 | 1·182478 | 8·818461 | 3205 | 1·181539 | 0·000939 | 14 | 9·999061 | 56 | 14 |
| 47 | 8 | 8·819436 | 3177 | 1·180564 | 8·820384 | 3191 | 1·179616 | 0·000947 | 14 | 9·999053 | 52 | 13 |
| 48 | 12 | 8·821343 | 3163 | 1·178657 | 8·822298 | 3177 | 1·177702 | 0·000956 | 14 | 9·999044 | 48 | 12 |
| 49 | 16 | 8·823240 | 3149 | 1·176760 | 8·824205 | 3163 | 1·175795 | 0·000964 | 14 | 9·999036 | 44 | 11 |
| 50 | 20 | 8·825130 | 3135 | 1·174870 | 8·826103 | 3150 | 1·173897 | 0·000973 | 14 | 9·999027 | 40 | 10 |
| 51 | 24 | 8·827011 | 3122 | 1·172989 | 8·827992 | 3136 | 1·172008 | 0·000981 | 14 | 9·999019 | 36 | 9 |
| 52 | 28 | 8·828884 | 3108 | 1·171116 | 8·829874 | 3123 | 1·170126 | 0·000990 | 14 | 9·999010 | 32 | 8 |
| 53 | 32 | 8·830749 | 3095 | 1·169251 | 8·831748 | 3108 | 1·168252 | 0·000998 | 14 | 9·999002 | 28 | 7 |
| 54 | 36 | 8·832607 | 3082 | 1·167393 | 8·833613 | 3096 | 1·166387 | 0·001007 | 14 | 9·998993 | 24 | 6 |
| 55 | 40 | 8·834456 | 3069 | 1·165544 | 8·835471 | 3083 | 1·164529 | 0·001016 | 14 | 9·998984 | 20 | 5 |
| 56 | 44 | 8·836297 | 3056 | 1·163703 | 8·837321 | 3070 | 1·162679 | 0·001024 | 14 | 9·998976 | 16 | 4 |
| 57 | 48 | 8·838130 | 3043 | 1·161870 | 8·839163 | 3057 | 1·160837 | 0·001033 | 15 | 9·998967 | 12 | 3 |
| 58 | 52 | 8·839956 | 3030 | 1·160044 | 8·840998 | 3045 | 1·159002 | 0·001042 | 15 | 9·998958 | 8 | 2 |
| 59 | 56 | 8·841774 | 3017 | 1·158226 | 8·842825 | 3032 | 1·157175 | 0·001050 | 15 | 9·998950 | 4 | 1 |
| 60 | **16** | 8·843585 | | 1·156415 | 8·844644 | | 1·155356 | 0·001059 | | 9·998941 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

93° $86° = 5^h\ 44^m$ 86°

## LOG. SINES, COSINES, &c.

4° 4°=0h 16m 175°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8·843585 | 3005 | 1·156415 | 8·844644 | 3019 | 1·155356 | 0·001059 | 15 | 9·998941 | **44** | 60 |
| 1 | 4 | 8·845387 | 2992 | 1·154613 | 8·846455 | 3007 | 1·153545 | 0·001068 | 15 | 9·998932 | 56 | 59 |
| 2 | 8 | 8·847183 | 2980 | 1·152817 | 8·848260 | 2995 | 1·151740 | 0·001077 | 15 | 9·998923 | 52 | 58 |
| 3 | 12 | 8·848971 | 2967 | 1·151029 | 8·850057 | 2982 | 1·149943 | 0·001086 | 15 | 9·998914 | 48 | 57 |
| 4 | 16 | 8·850751 | 2955 | 1·149249 | 8·851846 | 2970 | 1·148154 | 0·001095 | 15 | 9·998905 | 44 | 56 |
| 5 | 20 | 8·852525 | 2943 | 1·147475 | 8·853628 | 2958 | 1·146372 | 0·001104 | 15 | 9·998896 | 40 | 55 |
| 6 | 24 | 8·854291 | 2931 | 1·145709 | 8·855403 | 2946 | 1·144597 | 0·001113 | 15 | 9·998887 | 36 | 54 |
| 7 | 28 | 8·856049 | 2919 | 1·143951 | 8·857171 | 2935 | 1·142829 | 0·001122 | 15 | 9·998878 | 32 | 53 |
| 8 | 32 | 8·857801 | 2908 | 1·142199 | 8·858932 | 2923 | 1·141068 | 0·001131 | 15 | 9·998869 | 28 | 52 |
| 9 | 36 | 8·859546 | 2896 | 1·140454 | 8·860686 | 2911 | 1·139314 | 0·001140 | 15 | 9·998860 | 24 | 51 |
| 10 | 40 | 8·861283 | 2884 | 1·138717 | 8·862433 | 2900 | 1·137567 | 0·001149 | 15 | 9·998851 | 20 | 50 |
| 11 | 44 | 8·863014 | 2873 | 1·136986 | 8·864173 | 2888 | 1·135827 | 0·001159 | 15 | 9·998841 | 16 | 49 |
| 12 | 48 | 8·864738 | 2861 | 1·135262 | 8·865906 | 2877 | 1·134094 | 0·001168 | 15 | 9·998832 | 12 | 48 |
| 13 | 52 | 8·866455 | 2850 | 1·133545 | 8·867632 | 2866 | 1·132368 | 0·001177 | 16 | 9·998823 | 8 | 47 |
| 14 | 56 | 8·868165 | 2839 | 1·131835 | 8·869351 | 2854 | 1·130649 | 0·001187 | 16 | 9·998813 | 4 | 46 |
| 15 | **17** | 8·869868 | 2828 | 1·130132 | 8·871064 | 2843 | 1·128936 | 0·001196 | 16 | 9·998804 | **43** | 45 |
| 16 | 4 | 8·871565 | 2817 | 1·128435 | 8·872770 | 2832 | 1·127230 | 0·001205 | 16 | 9·998795 | 56 | 44 |
| 17 | 8 | 8·873255 | 2806 | 1·126745 | 8·874469 | 2821 | 1·125531 | 0·001215 | 16 | 9·998785 | 52 | 43 |
| 18 | 12 | 8·874938 | 2795 | 1·125062 | 8·876162 | 2811 | 1·123838 | 0·001224 | 16 | 9·998776 | 48 | 42 |
| 19 | 16 | 8·876615 | 2783 | 1·123385 | 8·877849 | 2800 | 1·122151 | 0·001234 | 16 | 9·998766 | 44 | 41 |
| 20 | 20 | 8·878285 | 2773 | 1·121715 | 8·879529 | 2789 | 1·120471 | 0·001243 | 16 | 9·998757 | 40 | 40 |
| 21 | 24 | 8·879949 | 2763 | 1·120051 | 8 881202 | 2779 | 1·118798 | 0·001253 | 16 | 9·998747 | 36 | 39 |
| 22 | 28 | 8·881607 | 2752 | 1·118393 | 8 882869 | 2768 | 1·117131 | 0·001262 | 16 | 9·998738 | 32 | 38 |
| 23 | 32 | 8·883258 | 2742 | 1·116742 | 8·884530 | 2758 | 1·115470 | 0·001272 | 16 | 9·998728 | 28 | 37 |
| 24 | 36 | 8·884903 | 2731 | 1·115097 | 8·886185 | 2747 | 1·113815 | 0·001282 | 16 | 9·998718 | 24 | 36 |
| 25 | 40 | 8·886542 | 2721 | 1·113458 | 8 887833 | 2737 | 1·112167 | 0·001292 | 16 | 9·998708 | 20 | 35 |
| 26 | 44 | 8·888174 | 2711 | 1·111826 | 8·889476 | 2727 | 1·110524 | 0·001301 | 16 | 9·998699 | 16 | 34 |
| 27 | 48 | 8·889801 | 2700 | 1·110199 | 8 891112 | 2717 | 1·108888 | 0·001311 | 16 | 9·998689 | 12 | 33 |
| 28 | 52 | 8·891421 | 2690 | 1·108579 | 8·892742 | 2707 | 1·107258 | 0·001321 | 16 | 9·998679 | 8 | 32 |
| 29 | 56 | 8·893035 | 2680 | 1·106965 | 8·894366 | 2697 | 1·105634 | 0·001331 | 17 | 9·998669 | 4 | 31 |
| 30 | **18** | 8·894643 | 2670 | 1·105357 | 8·895984 | 2687 | 1·104016 | 0·001341 | 17 | 9·998659 | **42** | 30 |
| 31 | 4 | 8·896246 | 2660 | 1·103754 | 8·897596 | 2677 | 1·102404 | 0·001351 | 17 | 9·998649 | 56 | 29 |
| 32 | 8 | 8·897842 | 2651 | 1·102158 | 8·899203 | 2667 | 1·100797 | 0·001361 | 17 | 9·998639 | 52 | 28 |
| 33 | 12 | 8·899432 | 2641 | 1·100568 | 8·900803 | 2658 | 1·099197 | 0·001371 | 17 | 9·998629 | 48 | 27 |
| 34 | 16 | 8·901017 | 2631 | 1·098983 | 8·902398 | 2648 | 1·097602 | 0·001381 | 17 | 9·998619 | 44 | 26 |
| 35 | 20 | 8·902596 | 2622 | 1·097404 | 8·903987 | 2638 | 1·096013 | 0·001391 | 17 | 9·998609 | 40 | 25 |
| 36 | 24 | 8·904169 | 2612 | 1·095831 | 8·905570 | 2629 | 1·094430 | 0·001401 | 17 | 9·998599 | 36 | 24 |
| 37 | 28 | 8·905736 | 2603 | 1·094264 | 8·907147 | 2620 | 1·092853 | 0·001411 | 17 | 9·998589 | 32 | 23 |
| 38 | 32 | 8·907297 | 2593 | 1·092703 | 8·908719 | 2610 | 1·091281 | 0·001422 | 17 | 9·998578 | 28 | 22 |
| 39 | 36 | 8·908853 | 2584 | 1·091147 | 8·910285 | 2601 | 1·089715 | 0·001432 | 17 | 9·998568 | 24 | 21 |
| 40 | 40 | 8·910404 | 2575 | 1·089596 | 8·911846 | 2592 | 1·088154 | 0·001442 | 17 | 9·998558 | 20 | 20 |
| 41 | 44 | 8·911949 | 2566 | 1·088051 | 8·913401 | 2583 | 1·086599 | 0·001452 | 17 | 9·998548 | 16 | 19 |
| 42 | 48 | 8·913488 | 2556 | 1·086512 | 8·914951 | 2574 | 1·085049 | 0·001463 | 17 | 9·998537 | 12 | 18 |
| 43 | 52 | 8·915022 | 2547 | 1·084978 | 8 916495 | 2565 | 1·083505 | 0·001473 | 17 | 9·998527 | 8 | 17 |
| 44 | 56 | 8·916550 | 2538 | 1·083450 | 8·918034 | 2556 | 1·081966 | 0·001484 | 18 | 9·998516 | 4 | 16 |
| 45 | **19** | 8·918073 | 2529 | 1·081927 | 8·919568 | 2547 | 1·080432 | 0·001494 | 18 | 9·998506 | **41** | 15 |
| 46 | 4 | 8·919591 | 2520 | 1·080409 | 8 921096 | 2538 | 1·078904 | 0·001505 | 18 | 9·998495 | 56 | 14 |
| 47 | 8 | 8·921103 | 2512 | 1·078897 | 8·922619 | 2530 | 1·077381 | 0·001515 | 18 | 9·998485 | 52 | 13 |
| 48 | 12 | 8·922610 | 2503 | 1·077390 | 8·924136 | 2521 | 1·075864 | 0·001526 | 18 | 9·998474 | 48 | 12 |
| 49 | 16 | 8·924112 | 2494 | 1·075888 | 8·925649 | 2512 | 1·074351 | 0·001536 | 18 | 9·998464 | 44 | 11 |
| 50 | 20 | 8·925609 | 2486 | 1·074391 | 8·927156 | 2503 | 1·072844 | 0·001547 | 18 | 9·998453 | 40 | 10 |
| 51 | 24 | 8·927100 | 2477 | 1·072900 | 8·928658 | 2495 | 1·071342 | 0·001558 | 18 | 9·998442 | 36 | 9 |
| 52 | 28 | 8·928587 | 2469 | 1·071413 | 8·930155 | 2486 | 1·069845 | 0·001569 | 18 | 9·998431 | 32 | 8 |
| 53 | 32 | 8·930068 | 2460 | 1·069932 | 8·931647 | 2478 | 1·068353 | 0·001579 | 18 | 9·998421 | 28 | 7 |
| 54 | 36 | 8·931544 | 2452 | 1·068456 | 8·933134 | 2470 | 1·066866 | 0·001590 | 18 | 9·998410 | 24 | 6 |
| 55 | 40 | 8·933015 | 2443 | 1·066985 | 8·934616 | 2461 | 1·065384 | 0·001601 | 18 | 9·998399 | 20 | 5 |
| 56 | 44 | 8·934481 | 2435 | 1·065519 | 8·936093 | 2453 | 1·063907 | 0·001612 | 18 | 9·998388 | 16 | 4 |
| 57 | 48 | 8·935942 | 2427 | 1·064058 | 8·937565 | 2445 | 1·062435 | 0·001623 | 18 | 9·998377 | 12 | 3 |
| 58 | 52 | 8·937398 | 2419 | 1·062602 | 8·939032 | 2437 | 1·060968 | 0·001634 | 18 | 9·998366 | 8 | 2 |
| 59 | 56 | 8·938850 | 2411 | 1·061150 | 8·940494 | 2430 | 1·059506 | 0·001645 | 18 | 9·998355 | 4 | 1 |
| 60 | **20** | 8·940296 | | 1·059704 | 8·941952 | | 1·058048 | 0·001656 | | 9·998344 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

94° 85°=5h 40m 85°

## LOG. SINES, COSINES, &c.

5° — 5°=0h 20m — 174°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8·940296 | 2403 | 1·059704 | 8·941952 | 2421 | 1·058048 | 0·001656 | 19 | 9·998344 | **40** | 60 |
| 1 | 4 | 8·941738 | 2394 | 1·058262 | 8·943404 | 2413 | 1·056596 | 0·001667 | 19 | 9·998333 | 56 | 59 |
| 2 | 8 | 8·943174 | 2387 | 1·056826 | 8·944852 | 2405 | 1·055148 | 0·001678 | 19 | 9·998322 | 52 | 58 |
| 3 | 12 | 8·944606 | 2379 | 1·055394 | 8·946295 | 2397 | 1·053705 | 0·001689 | 19 | 9·998311 | 48 | 57 |
| 4 | 16 | 8·946034 | 2371 | 1·053966 | 8·947734 | 2390 | 1·052266 | 0·001700 | 19 | 9·998300 | 44 | 56 |
| 5 | 20 | 8·947456 | 2363 | 1·052544 | 8·949168 | 2382 | 1·050832 | 0·001711 | 19 | 9·998289 | 40 | 55 |
| 6 | 24 | 8·948874 | 2355 | 1·051126 | 8·950597 | 2374 | 1·049403 | 0·001723 | 19 | 9·998277 | 36 | 54 |
| 7 | 28 | 8·950287 | 2348 | 1·049713 | 8·952021 | 2366 | 1·047979 | 0·001734 | 19 | 9·998266 | 32 | 53 |
| 8 | 32 | 8·951696 | 2340 | 1·048304 | 8·953441 | 2358 | 1·046559 | 0·001745 | 19 | 9·998255 | 28 | 52 |
| 9 | 36 | 8·953100 | 2332 | 1·046900 | 8·954856 | 2351 | 1·045144 | 0·001757 | 19 | 9·998243 | 24 | 51 |
| 10 | 40 | 8·954499 | 2325 | 1·045501 | 8·956267 | 2344 | 1·043733 | 0·001768 | 19 | 9·998232 | 20 | 50 |
| 11 | 44 | 8·955894 | 2317 | 1·044106 | 8·957674 | 2335 | 1·042326 | 0·001780 | 19 | 9·998220 | 16 | 49 |
| 12 | 48 | 8·957284 | 2310 | 1·042716 | 8·959075 | 2329 | 1·040925 | 0·001791 | 19 | 9·998209 | 12 | 48 |
| 13 | 52 | 8·958670 | 2302 | 1·041330 | 8·960473 | 2321 | 1·039527 | 0·001803 | 19 | 9·998197 | 8 | 47 |
| 14 | 56 | 8·960052 | 2295 | 1·039948 | 8·961866 | 2314 | 1·038134 | 0·001814 | 19 | 9·998186 | 4 | 46 |
| 15 | **21** | 8·961429 | 2288 | 1·038571 | 8·963255 | 2307 | 1·036745 | 0·001826 | 19 | 9·998174 | **39** | 45 |
| 16 | 4 | 8·962801 | 2280 | 1·037199 | 8·964639 | 2300 | 1·035361 | 0·001837 | 19 | 9·998163 | 56 | 44 |
| 17 | 8 | 8·964170 | 2273 | 1·035830 | 8·966019 | 2293 | 1·033981 | 0·001849 | 19 | 9·998151 | 52 | 43 |
| 18 | 12 | 8·965534 | 2266 | 1·034466 | 8·967394 | 2286 | 1·032606 | 0·001861 | 20 | 9·998139 | 48 | 42 |
| 19 | 16 | 8·966893 | 2259 | 1·033107 | 8·968766 | 2279 | 1·031234 | 0·001872 | 20 | 9·998128 | 44 | 41 |
| 20 | 20 | 8·968249 | 2252 | 1·031751 | 8·970133 | 2271 | 1·029867 | 0·001884 | 20 | 9·998116 | 40 | 40 |
| 21 | 24 | 8·969600 | 2245 | 1·030400 | 8·971496 | 2265 | 1·028504 | 0·001896 | 20 | 9·998104 | 36 | 39 |
| 22 | 28 | 8·970947 | 2238 | 1·029053 | 8·972855 | 2257 | 1·027145 | 0·001908 | 20 | 9·998092 | 32 | 38 |
| 23 | 32 | 8·972289 | 2231 | 1·027711 | 8·974209 | 2251 | 1·025791 | 0·001920 | 20 | 9·998080 | 28 | 37 |
| 24 | 36 | 8·973628 | 2224 | 1·026372 | 8·975560 | 2244 | 1·024440 | 0·001932 | 20 | 9·998068 | 24 | 36 |
| 25 | 40 | 8·974962 | 2217 | 1·025038 | 8·976906 | 2237 | 1·023094 | 0·001944 | 20 | 9·998056 | 20 | 35 |
| 26 | 44 | 8·976293 | 2210 | 1·023707 | 8·978248 | 2230 | 1·021752 | 0·001956 | 20 | 9·998044 | 16 | 34 |
| 27 | 48 | 8·977619 | 2203 | 1·022381 | 8·979586 | 2223 | 1·020414 | 0·001968 | 20 | 9·998032 | 12 | 33 |
| 28 | 52 | 8·978941 | 2197 | 1·021059 | 8·980921 | 2217 | 1·019079 | 0·001980 | 20 | 9·998020 | 8 | 32 |
| 29 | 56 | 8·980259 | 2190 | 1·019741 | 8·982251 | 2210 | 1·017749 | 0·001992 | 20 | 9·998008 | 4 | 31 |
| 30 | **22** | 8·981573 | 2183 | 1·018427 | 8·983577 | 2204 | 1·016423 | 0·002004 | 20 | 9·997996 | **38** | 30 |
| 31 | 4 | 8·982883 | 2177 | 1·017117 | 8·984899 | 2197 | 1·015101 | 0·002016 | 20 | 9·997984 | 56 | 29 |
| 32 | 8 | 8·984189 | 2170 | 1·015811 | 8·986217 | 2191 | 1·013783 | 0·002028 | 20 | 9·997972 | 52 | 28 |
| 33 | 12 | 8·985491 | 2163 | 1·014509 | 8·987532 | 2184 | 1·012468 | 0·002041 | 20 | 9·997959 | 48 | 27 |
| 34 | 16 | 8·986789 | 2157 | 1·013211 | 8·988842 | 2178 | 1·011158 | 0·002053 | 20 | 9·997947 | 44 | 26 |
| 35 | 20 | 8·988083 | 2150 | 1·011917 | 8·990149 | 2171 | 1·009851 | 0·002065 | 21 | 9·997935 | 40 | 25 |
| 36 | 24 | 8·989374 | 2144 | 1·010626 | 8·991451 | 2165 | 1·008549 | 0·002078 | 21 | 9·997922 | 36 | 24 |
| 37 | 28 | 8·990660 | 2138 | 1·009340 | 8·992750 | 2158 | 1·007250 | 0·002090 | 21 | 9·997910 | 32 | 23 |
| 38 | 32 | 8·991943 | 2131 | 1·008057 | 8·994045 | 2152 | 1·005955 | 0·002103 | 21 | 9·997897 | 28 | 22 |
| 39 | 36 | 8·993222 | 2125 | 1·006778 | 8·995337 | 2146 | 1·004663 | 0·002115 | 21 | 9·997885 | 24 | 21 |
| 40 | 40 | 8·994497 | 2119 | 1·005503 | 8·996624 | 2140 | 1·003376 | 0·002128 | 21 | 9·997872 | 20 | 20 |
| 41 | 44 | 8·995768 | 2112 | 1·004232 | 8·997908 | 2134 | 1·002092 | 0·002140 | 21 | 9·997860 | 16 | 19 |
| 42 | 48 | 8·997036 | 2106 | 1·002964 | 8·999188 | 2127 | 1·000812 | 0·002153 | 21 | 9·997847 | 12 | 18 |
| 43 | 52 | 8·998299 | 2100 | 1·001701 | 9·000465 | 2121 | 0·999535 | 0·002165 | 21 | 9·997835 | 8 | 17 |
| 44 | 56 | 8·999560 | 2094 | 1·000440 | 9·001738 | 2115 | 0·998262 | 0·002178 | 21 | 9·997822 | 4 | 16 |
| 45 | **23** | 9·000816 | 2088 | 0·999184 | 9·003007 | 2109 | 0·996993 | 0·002191 | 21 | 9·997809 | **37** | 15 |
| 46 | 4 | 9·002069 | 2082 | 0·997931 | 9·004272 | 2103 | 0·995728 | 0·002203 | 21 | 9·997797 | 56 | 14 |
| 47 | 8 | 9·003318 | 2076 | 0·996682 | 9·005534 | 2097 | 0·994466 | 0·002216 | 21 | 9·997784 | 52 | 13 |
| 48 | 12 | 9·004563 | 2070 | 0·995437 | 9·006792 | 2091 | 0·993208 | 0·002229 | 21 | 9·997771 | 48 | 12 |
| 49 | 16 | 9·005805 | 2064 | 0·994195 | 9·008047 | 2085 | 0·991953 | 0·002242 | 21 | 9·997758 | 44 | 11 |
| 50 | 20 | 9·007044 | 2058 | 0·992956 | 9·009298 | 2080 | 0·990702 | 0·002255 | 21 | 9·997745 | 40 | 10 |
| 51 | 24 | 9·008278 | 2052 | 0·991722 | 9·010546 | 2074 | 0·989454 | 0·002268 | 21 | 9·997732 | 36 | 9 |
| 52 | 28 | 9·009510 | 2046 | 0·990490 | 9·011790 | 2068 | 0·988210 | 0·002281 | 21 | 9·997719 | 32 | 8 |
| 53 | 32 | 9·010737 | 2040 | 0·989263 | 9·013031 | 2062 | 0·986969 | 0·002294 | 21 | 9·997706 | 28 | 7 |
| 54 | 36 | 9·011962 | 2034 | 0·988038 | 9·014268 | 2056 | 0·985732 | 0·002307 | 22 | 9·997693 | 24 | 6 |
| 55 | 40 | 9·013182 | 2029 | 0·986818 | 9·015502 | 2051 | 0·984498 | 0·002320 | 22 | 9·997680 | 20 | 5 |
| 56 | 44 | 9·014400 | 2023 | 0·985600 | 9·016732 | 2045 | 0·983268 | 0·002333 | 22 | 9·997667 | 16 | 4 |
| 57 | 48 | 9·015613 | 2017 | 0·984387 | 9·017959 | 2040 | 0·982041 | 0·002346 | 22 | 9·997654 | 12 | 3 |
| 58 | 52 | 9·016824 | 2012 | 0·983176 | 9·019183 | 2033 | 0·980817 | 0·002359 | 22 | 9·997641 | 8 | 2 |
| 59 | 56 | 9·018031 | 2006 | 0·981969 | 9·020403 | 2028 | 0·979597 | 0·002372 | 22 | 9·997628 | 4 | 1 |
| 60 | **24** | 9·019235 | | 0·980765 | 9·021620 | | 0·978380 | 0·002386 | | 9·997614 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

95° — 84°=5h 36m

## LOG. SINES, COSINES, &c.

6° 6°=0h 24m 173°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·019235 | 2000 | 0·980765 | 9·021620 | 2023 | 0·978380 | 0·002386 | 22 | 9 997614 | **36** | 60 |
| 1 | 4 | 9·020435 | 1995 | 0·979565 | 9 022834 | 2017 | 0·977166 | 0·002399 | 22 | 9 997601 | 56 | 59 |
| 2 | 8 | 9·021632 | 1989 | 0 978368 | 9 024044 | 2011 | 0 975956 | 0·002412 | 22 | 9 997588 | 52 | 58 |
| 3 | 12 | 9·022825 | 1984 | 0 977175 | 9 025251 | 2006 | 0·974749 | 0·002426 | 22 | 9 997574 | 48 | 57 |
| 4 | 16 | 9·024016 | 1978 | 0 975984 | 9 026455 | 2000 | 0 973545 | 0·002439 | 22 | 9 997561 | 44 | 56 |
| 5 | 20 | 9·025203 | 1973 | 0 974797 | 9 027655 | 1995 | 0 972345 | 0 002453 | 22 | 9 997547 | 40 | 55 |
| 6 | 24 | 9·026386 | 1967 | 0 973614 | 9 028852 | 1990 | 0 971148 | 0 002466 | 23 | 9 997534 | 36 | 54 |
| 7 | 28 | 9·027567 | 1962 | 0 972433 | 9 030046 | 1985 | 0·969954 | 0 002480 | 23 | 9 997520 | 32 | 53 |
| 8 | 32 | 9·028744 | 1957 | 0 971256 | 9 031237 | 1979 | 0 968763 | 0 002493 | 23 | 9 997507 | 28 | 52 |
| 9 | 36 | 9·029918 | 1951 | 0 970082 | 9 032425 | 1974 | 0 967575 | 0 002507 | 23 | 9 997493 | 24 | 51 |
| 10 | 40 | 9·031089 | 1946 | 0·968911 | 9·033609 | 1969 | 0 966391 | 0·002520 | 23 | 9 997480 | 20 | 50 |
| 11 | 44 | 9·032257 | 1941 | 0·967743 | 9 034791 | 1964 | 0·965209 | 0 002534 | 23 | 9 997466 | 16 | 49 |
| 12 | 48 | 9·033421 | 1936 | 0 966579 | 9 035969 | 1958 | 0 964031 | 0·002548 | 23 | 9 997452 | 12 | 48 |
| 13 | 52 | 9·034582 | 1930 | 0 965418 | 9 037144 | 1953 | 0 962856 | 0·002561 | 23 | 9 997439 | 8 | 47 |
| 14 | 56 | 9·035741 | 1925 | 0 964259 | 9 038316 | 1948 | 0 961684 | 0·002575 | 23 | 9·997425 | 4 | 46 |
| 15 | **25** | 9·036896 | 1920 | 0 963104 | 9 039485 | 1943 | 0 960515 | 0·002589 | 23 | 9·997411 | **35** | 45 |
| 16 | 4 | 9·038048 | 1915 | 0 961952 | 9 040651 | 1938 | 0 959349 | 0·002603 | 23 | 9·997397 | 56 | 44 |
| 17 | 8 | 9·039197 | 1910 | 0 960803 | 9 041813 | 1933 | 0·958187 | 0·002617 | 23 | 9·997383 | 52 | 43 |
| 18 | 12 | 9·040342 | 1905 | 0 959658 | 9 042973 | 1928 | 0·957027 | 0·002631 | 23 | 9·997369 | 48 | 42 |
| 19 | 16 | 9·041485 | 1899 | 0 958515 | 9 044130 | 1923 | 0·955870 | 0·002645 | 23 | 9·997355 | 44 | 41 |
| 20 | 20 | 9·042625 | 1895 | 0 957375 | 9 045284 | 1918 | 0 954716 | 0·002659 | 23 | 9 997341 | 40 | 40 |
| 21 | 24 | 9·043762 | 1889 | 0 956238 | 9 046434 | 1913 | 0·953566 | 0·002673 | 24 | 9·997327 | 36 | 39 |
| 22 | 28 | 9·044895 | 1884 | 0 955105 | 9·047582 | 1908 | 0·952418 | 0·002687 | 24 | 9·997313 | 32 | 38 |
| 23 | 32 | 9·046026 | 1879 | 0 953974 | 9 048727 | 1903 | 0·951273 | 0·002701 | 24 | 9 997299 | 28 | 37 |
| 24 | 36 | 9·047154 | 1875 | 0·952846 | 9 049869 | 1898 | 0·950131 | 0·002715 | 24 | 9 997285 | 24 | 36 |
| 25 | 40 | 9·048279 | 1870 | 0 951721 | 9 051008 | 1893 | 0·948992 | 0·002729 | 24 | 9 997271 | 20 | 35 |
| 26 | 44 | 9·049400 | 1865 | 0 950600 | 9 052144 | 1889 | 0 947856 | 0·002743 | 24 | 9·997257 | 16 | 34 |
| 27 | 48 | 9·050519 | 1860 | 0·949481 | 9 053277 | 1884 | 0·946723 | 0·002758 | 24 | 9·997242 | 12 | 33 |
| 28 | 52 | 9·051635 | 1855 | 0·948365 | 9 054407 | 1879 | 0·945593 | 0·002772 | 24 | 9·997228 | 8 | 32 |
| 29 | 56 | 9·052749 | 1850 | 0·947251 | 9 055535 | 1874 | 0·944465 | 0·002786 | 24 | 9·997214 | 4 | 31 |
| 30 | **26** | 9·053859 | 1845 | 0·946141 | 9·056659 | 1870 | 0·943341 | 0·002801 | 24 | 9 997199 | **34** | 30 |
| 31 | 4 | 9·054966 | 1841 | 0·945034 | 9·057781 | 1865 | 0·942219 | 0·002815 | 24 | 9·997185 | 56 | 29 |
| 32 | 8 | 9·056071 | 1836 | 0·943929 | 9·058900 | 1860 | 0·941100 | 0·002830 | 24 | 9·997170 | 52 | 28 |
| 33 | 12 | 9·057172 | 1831 | 0·942828 | 9·060016 | 1855 | 0·939984 | 0·002844 | 24 | 9·997156 | 48 | 27 |
| 34 | 16 | 9·058271 | 1827 | 0·941729 | 9·061130 | 1851 | 0·938870 | 0·002859 | 24 | 9·997141 | 44 | 26 |
| 35 | 20 | 9·059367 | 1822 | 0·940633 | 9·062240 | 1846 | 0·937760 | 0·002873 | 24 | 9·997127 | 40 | 25 |
| 36 | 24 | 9·060460 | 1817 | 0·939540 | 9·063348 | 1842 | 0·936652 | 0·002888 | 24 | 9·997112 | 36 | 24 |
| 37 | 28 | 9·061551 | 1813 | 0·938449 | 9·064453 | 1837 | 0·935547 | 0·002902 | 24 | 9·997098 | 32 | 23 |
| 38 | 32 | 9·062639 | 1808 | 0·937361 | 9·065556 | 1833 | 0·934444 | 0·002917 | 25 | 9·997083 | 28 | 22 |
| 39 | 36 | 9·063724 | 1804 | 0·936276 | 9·066655 | 1828 | 0·933345 | 0·002932 | 25 | 9·997068 | 24 | 21 |
| 40 | 40 | 9·064806 | 1799 | 0·935194 | 9·067752 | 1824 | 0·932248 | 0·002947 | 25 | 9·997053 | 20 | 20 |
| 41 | 44 | 9·065885 | 1794 | 0·934115 | 9·068846 | 1819 | 0·931154 | 0·002961 | 25 | 9·997039 | 16 | 19 |
| 42 | 48 | 9·066962 | 1790 | 0·933038 | 9·069938 | 1815 | 0·930062 | 0·002976 | 25 | 9·997024 | 12 | 18 |
| 43 | 52 | 9·068036 | 1786 | 0·931964 | 9·071027 | 1810 | 0·928973 | 0·002991 | 25 | 9·997009 | 8 | 17 |
| 44 | 56 | 9·069107 | 1781 | 0·930893 | 9·072113 | 1806 | 0·927887 | 0·003006 | 25 | 9·996994 | 4 | 16 |
| 45 | **27** | 9·070176 | 1777 | 0·929824 | 9·073197 | 1802 | 0·926803 | 0·003021 | 25 | 9·996979 | **33** | 15 |
| 46 | 4 | 9·071242 | 1772 | 0·928758 | 9·074278 | 1797 | 0·925722 | 0·003036 | 25 | 9·996964 | 56 | 14 |
| 47 | 8 | 9·072306 | 1768 | 0·927694 | 9·075356 | 1793 | 0·924644 | 0·003051 | 25 | 9·996949 | 52 | 13 |
| 48 | 12 | 9·073366 | 1763 | 0·926634 | 9·076432 | 1789 | 0·923568 | 0·003066 | 25 | 9·996934 | 48 | 12 |
| 49 | 16 | 9·074424 | 1759 | 0·925576 | 9·077505 | 1784 | 0·922495 | 0·003081 | 25 | 9·996919 | 44 | 11 |
| 50 | 20 | 9·075480 | 1755 | 0·924520 | 9·078576 | 1780 | 0·921424 | 0·003096 | 25 | 9·996904 | 40 | 10 |
| 51 | 24 | 9·076533 | 1750 | 0·923467 | 9·079644 | 1776 | 0·920356 | 0·003111 | 25 | 9·996889 | 36 | 9 |
| 52 | 28 | 9·077583 | 1746 | 0·922417 | 9·080710 | 1772 | 0·919290 | 0·003126 | 25 | 9·996874 | 32 | 8 |
| 53 | 32 | 9·078631 | 1742 | 0·921369 | 9·081773 | 1767 | 0·918227 | 0·003142 | 25 | 9·996858 | 28 | 7 |
| 54 | 36 | 9·079676 | 1738 | 0·920324 | 9·082833 | 1763 | 0·917167 | 0·003157 | 25 | 9·996843 | 24 | 6 |
| 55 | 40 | 9·080719 | 1733 | 0·919281 | 9·083891 | 1759 | 0·916109 | 0·003172 | 25 | 9·996828 | 20 | 5 |
| 56 | 44 | 9·081759 | 1729 | 0·918241 | 9·084947 | 1755 | 0·915053 | 0·003188 | 26 | 9·996812 | 16 | 4 |
| 57 | 48 | 9·082797 | 1725 | 0·917203 | 9·086000 | 1751 | 0·914000 | 0·003203 | 26 | 9·996797 | 12 | 3 |
| 58 | 52 | 9·083832 | 1721 | 0·916168 | 9·087050 | 1747 | 0·912950 | 0·003218 | 26 | 9·996782 | 8 | 2 |
| 59 | 56 | 9·084864 | 1717 | 0·915136 | 9·088098 | 1743 | 0·911902 | 0·003234 | 26 | 9·996766 | 4 | 1 |
| 60 | **28** | 9·085894 | | 0·914106 | 9·089144 | | 0·910856 | 0·003249 | | 9·996751 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

96° 83°=5h 32m 83°

## LOG. SINES, COSINES, &c.

7° — 7°=0h 28m — 172°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·085894 | 1713 | 0 914106 | 9·089144 | 1738 | 0 910856 | 0 003249 | 26 | 9 996751 | 32 | 60 |
| 1 | 4 | 9 086922 | 1709 | 0 913078 | 9 090187 | 1735 | 0 909813 | 0 003265 | 26 | 9 996735 | 56 | 59 |
| 2 | 8 | 9·087947 | 1704 | 0 912053 | 9 091228 | 1731 | 0 908772 | 0 003280 | 26 | 9 996720 | 52 | 58 |
| 3 | 12 | 9·088970 | 1700 | 0 911030 | 9 092266 | 1727 | 0 907734 | 0 003296 | 26 | 9 996704 | 48 | 57 |
| 4 | 16 | 9 089990 | 1696 | 0 910010 | 9 093302 | 1722 | 0 906698 | 0 003312 | 26 | 9 996688 | 44 | 56 |
| 5 | 20 | 9 091008 | 1692 | 0 908992 | 9 094336 | 1719 | 0 905664 | 0·003327 | 26 | 9 996673 | 40 | 55 |
| 6 | 24 | 9 092024 | 1688 | 0 907976 | 9 095367 | 1715 | 0 904633 | 0·003343 | 26 | 9 996657 | 36 | 54 |
| 7 | 28 | 9 093037 | 1684 | 0 906963 | 9 096395 | 1711 | 0 903605 | 0 003359 | 26 | 9 996641 | 32 | 53 |
| 8 | 32 | 9·094047 | 1680 | 0 905953 | 9 097422 | 1707 | 0 902578 | 0 003375 | 26 | 9 996625 | 28 | 52 |
| 9 | 36 | 9 095056 | 1676 | 0 904944 | 9 098446 | 1703 | 0 901554 | 0 003390 | 26 | 9 996610 | 24 | 51 |
| 10 | 40 | 9 096062 | 1673 | 0 903938 | 9 099468 | 1699 | 0 900532 | 0 003406 | 26 | 9 996594 | 20 | 50 |
| 11 | 44 | 9·097065 | 1668 | 0 902935 | 9 100487 | 1695 | 0 899513 | 0 003422 | 27 | 9 996578 | 16 | 49 |
| 12 | 48 | 9 098066 | 1665 | 0 901934 | 9 101504 | 1691 | 0 898496 | 0 003438 | 27 | 9 996562 | 12 | 48 |
| 13 | 52 | 9 099065 | 1661 | 0 900935 | 9 102519 | 1687 | 0 897481 | 0·003454 | 27 | 9 996546 | 8 | 47 |
| 14 | 56 | 9 100062 | 1657 | 0 899938 | 9 103532 | 1684 | 0 896468 | 0 003470 | 27 | 9 996530 | 4 | 46 |
| 15 | 29 | 9·101056 | 1653 | 0 898944 | 9 104542 | 1680 | 0 895458 | 0·003486 | 27 | 9 996514 | 31 | 45 |
| 16 | 4 | 9·102048 | 1649 | 0 897952 | 9 105550 | 1676 | 0 894450 | 0·003502 | 27 | 9 996498 | 56 | 44 |
| 17 | 8 | 9·103037 | 1645 | 0 896963 | 9 106556 | 1672 | 0 893444 | 0·003518 | 27 | 9·996482 | 52 | 43 |
| 18 | 12 | 9 104025 | 1642 | 0 895975 | 9 107559 | 1669 | 0 892441 | 0 003535 | 27 | 9 996465 | 48 | 42 |
| 19 | 16 | 9 105010 | 1638 | 0 894990 | 9 108560 | 1665 | 0 891440 | 0 003551 | 27 | 9 996449 | 44 | 41 |
| 20 | 20 | 9·105992 | 1634 | 0 894008 | 9 109559 | 1661 | 0 890441 | 0 003567 | 27 | 9 996433 | 40 | 40 |
| 21 | 24 | 9 106973 | 1630 | 0 893027 | 9 110556 | 1658 | 0 889444 | 0 003583 | 27 | 9 996417 | 36 | 39 |
| 22 | 28 | 9·107951 | 1627 | 0 892049 | 9 111551 | 1654 | 0 888449 | 0 003600 | 27 | 9 996400 | 32 | 38 |
| 23 | 32 | 9·108927 | 1623 | 0 891073 | 9 112543 | 1650 | 0 887457 | 0 003616 | 27 | 9 996384 | 28 | 37 |
| 24 | 36 | 9·109901 | 1619 | 0 890099 | 9 113533 | 1647 | 0 886467 | 0 003632 | 27 | 9 996368 | 24 | 36 |
| 25 | 40 | 9 110873 | 1616 | 0 889127 | 9 114521 | 1643 | 0 885479 | 0·003649 | 27 | 9 996351 | 20 | 35 |
| 26 | 44 | 9 111842 | 1612 | 0 888158 | 9 115507 | 1639 | 0 884493 | 0 003665 | 27 | 9 996335 | 16 | 34 |
| 27 | 48 | 9 112809 | 1608 | 0 887191 | 9 116491 | 1636 | 0 883509 | 0 003682 | 27 | 9 996318 | 12 | 33 |
| 28 | 52 | 9 113774 | 1605 | 0 886226 | 9 117472 | 1632 | 0 882528 | 0·003698 | 28 | 9 996302 | 8 | 32 |
| 29 | 56 | 9 114737 | 1601 | 0 885263 | 9 118452 | 1629 | 0 881548 | 0 003715 | 28 | 9 996285 | 4 | 31 |
| 30 | 30 | 9·115698 | 1597 | 0 884302 | 9 119429 | 1625 | 0 880571 | 0 003731 | 28 | 9 996269 | 30 | 30 |
| 31 | 4 | 9 116656 | 1594 | 0 883344 | 9 120404 | 1622 | 0 879596 | 0·003748 | 28 | 9 996252 | 56 | 29 |
| 32 | 8 | 9 117613 | 1590 | 0 882387 | 9 121377 | 1618 | 0 878623 | 0·003765 | 28 | 9 996235 | 52 | 28 |
| 33 | 12 | 9·118567 | 1587 | 0·881433 | 9·122348 | 1615 | 0·877652 | 0·003781 | 28 | 9 996219 | 48 | 27 |
| 34 | 16 | 9·119519 | 1583 | 0 880481 | 9 123317 | 1611 | 0 876683 | 0·003798 | 28 | 9 996202 | 44 | 26 |
| 35 | 20 | 9·120469 | 1580 | 0 879531 | 9 124284 | 1608 | 0 875716 | 0·003815 | 28 | 9 996185 | 40 | 25 |
| 36 | 24 | 9·121417 | 1576 | 0 878583 | 9 125249 | 1604 | 0·874751 | 0 003832 | 28 | 9 996168 | 36 | 24 |
| 37 | 28 | 9·122362 | 1573 | 0 877638 | 9 126211 | 1601 | 0·873789 | 0·003849 | 28 | 9·996151 | 32 | 23 |
| 38 | 32 | 9·123306 | 1569 | 0·876694 | 9 127172 | 1597 | 0 872828 | 0 003866 | 28 | 9 996134 | 28 | 22 |
| 39 | 36 | 9·124248 | 1566 | 0 875752 | 9 128130 | 1594 | 0·871870 | 0 003883 | 28 | 9 996117 | 24 | 21 |
| 40 | 40 | 9·125187 | 1562 | 0·874813 | 9 129087 | 1591 | 0·870913 | 0·003900 | 28 | 9 996100 | 20 | 20 |
| 41 | 44 | 9·126125 | 1559 | 0 873875 | 9 130041 | 1587 | 0·869959 | 0 003917 | 29 | 9 996083 | 16 | 19 |
| 42 | 48 | 9·127060 | 1556 | 0 872940 | 9·130994 | 1584 | 0·869006 | 0·003934 | 29 | 9 996066 | 12 | 18 |
| 43 | 52 | 9·127993 | 1552 | 0 872007 | 9·131944 | 1581 | 0·868056 | 0 003951 | 29 | 9 996049 | 8 | 17 |
| 44 | 56 | 9·128925 | 1549 | 0 871075 | 9 132893 | 1577 | 0·867107 | 0·003968 | 29 | 9 996032 | 4 | 16 |
| 45 | 31 | 9·129854 | 1545 | 0·870146 | 9·133839 | 1574 | 0·866161 | 0·003985 | 29 | 9 996015 | 29 | 15 |
| 46 | 4 | 9·130781 | 1542 | 0·869219 | 9·134784 | 1571 | 0·865216 | 0·004002 | 29 | 9 995998 | 56 | 14 |
| 47 | 8 | 9·131706 | 1539 | 0·868294 | 9·135726 | 1567 | 0·864274 | 0·004020 | 29 | 9 995980 | 52 | 13 |
| 48 | 12 | 9·132630 | 1535 | 0·867370 | 9·136667 | 1564 | 0·863333 | 0·004037 | 29 | 9 995963 | 48 | 12 |
| 49 | 16 | 9·133551 | 1532 | 0·866449 | 9·137605 | 1561 | 0·862395 | 0·004054 | 29 | 9·995946 | 44 | 11 |
| 50 | 20 | 9·134470 | 1529 | 0·865530 | 9 138542 | 1558 | 0·861458 | 0·004072 | 29 | 9 995928 | 40 | 10 |
| 51 | 24 | 9·135387 | 1525 | 0·864613 | 9 139476 | 1555 | 0·860524 | 0·004089 | 29 | 9 995911 | 36 | 9 |
| 52 | 28 | 9·136303 | 1522 | 0·863697 | 9 140409 | 1551 | 0·859591 | 0·004106 | 29 | 9 995894 | 32 | 8 |
| 53 | 32 | 9·137216 | 1519 | 0·862784 | 9·141340 | 1548 | 0·858660 | 0·004124 | 29 | 9 995876 | 28 | 7 |
| 54 | 36 | 9·138128 | 1516 | 0·861872 | 9·142269 | 1545 | 0·857731 | 0·004141 | 29 | 9·995859 | 24 | 6 |
| 55 | 40 | 9·139037 | 1512 | 0·860963 | 9·143196 | 1542 | 0·856804 | 0·004159 | 29 | 9 995841 | 20 | 5 |
| 56 | 44 | 9·139944 | 1509 | 0·860056 | 9·144121 | 1539 | 0·855879 | 0·004177 | 29 | 9 995823 | 16 | 4 |
| 57 | 48 | 9·140850 | 1506 | 0·859150 | 9·145044 | 1535 | 0·854956 | 0·004194 | 29 | 9 995806 | 12 | 3 |
| 58 | 52 | 9·141754 | 1503 | 0·858246 | 9·145966 | 1532 | 0·854034 | 0·004212 | 29 | 9·995788 | 8 | 2 |
| 59 | 56 | 9·142655 | 1500 | 0·857345 | 9·146885 | 1529 | 0·853115 | 0·004229 | 29 | 9 995771 | 4 | 1 |
| 60 | 32 | 9·143555 | | 0·856445 | 9·147803 | | 0 852197 | 0·004247 | | 9 995753 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

97° — 82°=5h 28m — 82°

## LOG. SINES, COSINES, &c.

8° | 8° = 0h 32m | 171°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·143555 | 1496 | 0·856445 | 9·147803 | 1526 | 0·852197 | 0·004247 | 30 | 9·995753 | **28** | 60 |
| 1 | 4 | 9·144453 | 1493 | 0·855547 | 9·148718 | 1523 | 0·851282 | 0·004265 | 30 | 9·995735 | 56 | 59 |
| 2 | 8 | 9·145349 | 1490 | 0·854651 | 9·149632 | 1520 | 0·850368 | 0·004283 | 30 | 9·995717 | 52 | 58 |
| 3 | 12 | 9·146243 | 1487 | 0·853757 | 9·150544 | 1517 | 0·849456 | 0·004301 | 30 | 9·995699 | 48 | 57 |
| 4 | 16 | 9·147136 | 1484 | 0·852864 | 9·151454 | 1514 | 0·848546 | 0·004319 | 30 | 9·995681 | 44 | 56 |
| 5 | 20 | 9·148026 | 1481 | 0·851974 | 9·152363 | 1511 | 0·847637 | 0·004336 | 30 | 9·995664 | 40 | 55 |
| 6 | 24 | 9·148915 | 1478 | 0·851085 | 9·153269 | 1508 | 0·846731 | 0·004354 | 30 | 9·995646 | 36 | 54 |
| 7 | 28 | 9·149802 | 1475 | 0·850198 | 9·154174 | 1505 | 0·845826 | 0·004372 | 30 | 9·995628 | 32 | 53 |
| 8 | 32 | 9·150686 | 1472 | 0·849314 | 9·155077 | 1502 | 0·844923 | 0·004390 | 30 | 9·995610 | 28 | 52 |
| 9 | 36 | 9·151569 | 1469 | 0·848431 | 9·155978 | 1499 | 0·844022 | 0·004409 | 30 | 9·995591 | 24 | 51 |
| 10 | 40 | 9·152451 | 1466 | 0·847549 | 9·156877 | 1496 | 0·843123 | 0·004427 | 30 | 9·995573 | 20 | 50 |
| 11 | 44 | 9·153330 | 1463 | 0·846670 | 9·157775 | 1493 | 0·842225 | 0·004445 | 30 | 9·995555 | 16 | 49 |
| 12 | 48 | 9·154208 | 1460 | 0·845792 | 9·158671 | 1490 | 0·841329 | 0·004463 | 30 | 9·995537 | 12 | 48 |
| 13 | 52 | 9·155083 | 1457 | 0·844917 | 9·159565 | 1487 | 0·840435 | 0·004481 | 30 | 9·995519 | 8 | 47 |
| 14 | 56 | 9·155957 | 1454 | 0·844043 | 9·160457 | 1484 | 0·839543 | 0·004499 | 31 | 9·995501 | 4 | 46 |
| 15 | **33** | 9·156830 | 1451 | 0·843170 | 9·161347 | 1481 | 0·838653 | 0·004518 | 31 | 9·995482 | **27** | 45 |
| 16 | 4 | 9·157700 | 1448 | 0·842300 | 9·162236 | 1479 | 0·837764 | 0·004536 | 31 | 9·995464 | 56 | 44 |
| 17 | 8 | 9·158569 | 1445 | 0·841431 | 9·163123 | 1476 | 0·836877 | 0·004554 | 31 | 9·995446 | 52 | 43 |
| 18 | 12 | 9·159435 | 1442 | 0·840565 | 9·164008 | 1473 | 0·835992 | 0·004573 | 31 | 9·995427 | 48 | 42 |
| 19 | 16 | 9·160301 | 1439 | 0·839699 | 9·164892 | 1470 | 0·835108 | 0·004591 | 31 | 9·995409 | 44 | 41 |
| 20 | 20 | 9·161164 | 1436 | 0·838836 | 9·165774 | 1467 | 0·834226 | 0·004610 | 31 | 9·995390 | 40 | 40 |
| 21 | 24 | 9·162025 | 1433 | 0·837975 | 9·166654 | 1464 | 0·833346 | 0·004628 | 31 | 9·995372 | 36 | 39 |
| 22 | 28 | 9·162885 | 1430 | 0·837115 | 9·167532 | 1461 | 0·832468 | 0·004647 | 31 | 9·995353 | 32 | 38 |
| 23 | 32 | 9·163743 | 1427 | 0·836257 | 9·168409 | 1458 | 0·831591 | 0·004666 | 31 | 9·995334 | 28 | 37 |
| 24 | 36 | 9·164600 | 1424 | 0·835400 | 9·169284 | 1455 | 0·830716 | 0·004684 | 31 | 9·995316 | 24 | 36 |
| 25 | 40 | 9·165454 | 1422 | 0·834546 | 9·170157 | 1453 | 0·829843 | 0·004703 | 31 | 9·995297 | 20 | 35 |
| 26 | 44 | 9·166307 | 1419 | 0·833693 | 9·171029 | 1450 | 0·828971 | 0·004722 | 31 | 9·995278 | 16 | 34 |
| 27 | 48 | 9·167159 | 1416 | 0·832841 | 9·171899 | 1447 | 0·828101 | 0·004740 | 31 | 9·995260 | 12 | 33 |
| 28 | 52 | 9·168008 | 1413 | 0·831992 | 9·172767 | 1444 | 0·827233 | 0·004759 | 32 | 9·995241 | 8 | 32 |
| 29 | 56 | 9·168856 | 1410 | 0·831144 | 9·173634 | 1442 | 0·826366 | 0·004778 | 32 | 9·995222 | 4 | 31 |
| 30 | **34** | 9·169702 | 1407 | 0·830298 | 9·174499 | 1439 | 0·825501 | 0·004797 | 32 | 9·995203 | **26** | 30 |
| 31 | 4 | 9·170547 | 1405 | 0·829453 | 9·175362 | 1436 | 0·824638 | 0·004816 | 32 | 9·995184 | 56 | 29 |
| 32 | 8 | 9·171389 | 1402 | 0·828611 | 9·176224 | 1433 | 0·823776 | 0·004835 | 32 | 9·995165 | 52 | 28 |
| 33 | 12 | 9·172230 | 1399 | 0·827770 | 9·177084 | 1431 | 0·822916 | 0·004854 | 32 | 9·995146 | 48 | 27 |
| 34 | 16 | 9·173070 | 1396 | 0·826930 | 9·177942 | 1428 | 0·822058 | 0·004873 | 32 | 9·995127 | 44 | 26 |
| 35 | 20 | 9·173908 | 1393 | 0·826092 | 9·178799 | 1425 | 0·821201 | 0·004892 | 32 | 9·995108 | 40 | 25 |
| 36 | 24 | 9·174744 | 1391 | 0·825256 | 9·179655 | 1423 | 0·820345 | 0·004911 | 32 | 9·995089 | 36 | 24 |
| 37 | 28 | 9·175578 | 1388 | 0·824422 | 9·180508 | 1420 | 0·819492 | 0·004930 | 32 | 9·995070 | 32 | 23 |
| 38 | 32 | 9·176411 | 1386 | 0·823589 | 9·181360 | 1417 | 0·818640 | 0·004949 | 32 | 9·995051 | 28 | 22 |
| 39 | 36 | 9·177242 | 1383 | 0·822758 | 9·182211 | 1415 | 0·817789 | 0·004968 | 32 | 9·995032 | 24 | 21 |
| 40 | 40 | 9·178072 | 1380 | 0·821928 | 9·183059 | 1412 | 0·816941 | 0·004987 | 32 | 9·995013 | 20 | 20 |
| 41 | 44 | 9·178900 | 1377 | 0·821100 | 9·183907 | 1409 | 0·816093 | 0·005007 | 32 | 9·994993 | 16 | 19 |
| 42 | 48 | 9·179726 | 1374 | 0·820274 | 9·184752 | 1407 | 0·815248 | 0·005026 | 32 | 9·994974 | 12 | 18 |
| 43 | 52 | 9·180551 | 1372 | 0·819449 | 9·185597 | 1404 | 0·814403 | 0·005045 | 32 | 9·994955 | 8 | 17 |
| 44 | 56 | 9·181374 | 1369 | 0·818626 | 9·186439 | 1402 | 0·813561 | 0·005065 | 32 | 9·994935 | 4 | 16 |
| 45 | **35** | 9·182196 | 1366 | 0·817804 | 9·187280 | 1399 | 0·812720 | 0·005084 | 33 | 9·994916 | **25** | 15 |
| 46 | 4 | 9·183016 | 1364 | 0·816984 | 9·188120 | 1396 | 0·811880 | 0·005104 | 33 | 9·994896 | 56 | 14 |
| 47 | 8 | 9·183834 | 1361 | 0·816166 | 9·188958 | 1393 | 0·811042 | 0·005123 | 33 | 9·994877 | 52 | 13 |
| 48 | 12 | 9·184651 | 1359 | 0·815349 | 9·189794 | 1391 | 0·810206 | 0·005143 | 33 | 9·994857 | 48 | 12 |
| 49 | 16 | 9·185466 | 1356 | 0·814534 | 9·190629 | 1389 | 0·809371 | 0·005162 | 33 | 9·994838 | 44 | 11 |
| 50 | 20 | 9·186280 | 1353 | 0·813720 | 9·191462 | 1386 | 0·808538 | 0·005182 | 33 | 9·994818 | 40 | 10 |
| 51 | 24 | 9·187092 | 1351 | 0·812908 | 9·192294 | 1384 | 0·807706 | 0·005202 | 33 | 9·994798 | 36 | 9 |
| 52 | 28 | 9·187903 | 1348 | 0·812097 | 9·193124 | 1381 | 0·806876 | 0·005221 | 33 | 9·994779 | 32 | 8 |
| 53 | 32 | 9·188712 | 1346 | 0·811288 | 9·193953 | 1379 | 0·806047 | 0·005241 | 33 | 9·994759 | 28 | 7 |
| 54 | 36 | 9·189519 | 1343 | 0·810481 | 9·194780 | 1376 | 0·805220 | 0·005261 | 33 | 9·994739 | 24 | 6 |
| 55 | 40 | 9·190325 | 1341 | 0·809675 | 9·195606 | 1374 | 0·804394 | 0·005281 | 33 | 9·994719 | 20 | 5 |
| 56 | 44 | 9·191130 | 1338 | 0·808870 | 9·196430 | 1371 | 0·803570 | 0·005300 | 33 | 9·994700 | 16 | 4 |
| 57 | 48 | 9·191933 | 1336 | 0·808067 | 9·197253 | 1369 | 0·802747 | 0·005320 | 33 | 9·994680 | 12 | 3 |
| 58 | 52 | 9·192734 | 1333 | 0·807266 | 9·198074 | 1366 | 0·801926 | 0·005340 | 33 | 9·994660 | 8 | 2 |
| 59 | 56 | 9·193534 | 1330 | 0·806466 | 9·198894 | 1364 | 0·801106 | 0·005360 | 33 | 9·994640 | 4 | 1 |
| 60 | **36** | 9·194332 | | 0·805668 | 9·199713 | | 0·800287 | 0·005380 | | 9·994620 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. S. | ′ |

98° | 81° = 5h 24m | 81°

## LOG. SINES, COSINES, &c.

9° — 9°=0h 36m — 170°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·194332 | 1328 | 0 805668 | 9 199713 | 1361 | 0·800287 | 0·005380 | 33 | 9 994620 | **24** | 60 |
| 1 | 4 | 9·195129 | 1326 | 0 804871 | 9 200529 | 1359 | 0·799471 | 0·005400 | 33 | 9 994600 | 56 | 59 |
| 2 | 8 | 9·195925 | 1323 | 0 804075 | 9 201345 | 1356 | 0·798655 | 0·005420 | 33 | 9 994580 | 52 | 58 |
| 3 | 12 | 9·196719 | 1321 | 0 803281 | 9 202159 | 1354 | 0·797841 | 0·005440 | 34 | 9 994560 | 48 | 57 |
| 4 | 16 | 9·197511 | 1318 | 0 802489 | 9 202971 | 1352 | 0·797029 | 0·005460 | 34 | 9 994540 | 44 | 56 |
| 5 | 20 | 9·198302 | 1316 | 0 801698 | 9 203782 | 1349 | 0·796218 | 0·005481 | 34 | 9 994519 | 40 | 55 |
| 6 | 24 | 9·199091 | 1313 | 0 800909 | 9 204592 | 1347 | 0·795408 | 0·005501 | 34 | 9 994499 | 36 | 54 |
| 7 | 28 | 9·199879 | 1311 | 0 800121 | 9 205400 | 1345 | 0·794600 | 0·005521 | 34 | 9 994479 | 32 | 53 |
| 8 | 32 | 9·200666 | 1308 | 0 799334 | 9 206207 | 1342 | 0·793793 | 0·005541 | 34 | 9 994459 | 28 | 52 |
| 9 | 36 | 9·201451 | 1306 | 0 798549 | 9 207013 | 1340 | 0·792987 | 0·005562 | 34 | 9 994438 | 24 | 51 |
| 10 | 40 | 9·202234 | 1304 | 0·797766 | 9 207817 | 1338 | 0·792183 | 0·005582 | 34 | 9 994418 | 20 | 50 |
| 11 | 44 | 9·203017 | 1301 | 0 796983 | 9 208619 | 1335 | 0·791381 | 0·005602 | 34 | 9 994398 | 16 | 49 |
| 12 | 48 | 9·203797 | 1299 | 0 796203 | 9 209420 | 1333 | 0·790580 | 0·005623 | 34 | 9 994377 | 12 | 48 |
| 13 | 52 | 9·204577 | 1296 | 0 795423 | 9 210220 | 1331 | 0 789780 | 0·005643 | 34 | 9 994357 | 8 | 47 |
| 14 | 56 | 9 205354 | 1294 | 0 794646 | 9 211018 | 1328 | 0·788982 | 0·005664 | 34 | 9 994336 | 4 | 46 |
| 15 | **37** | 9·206131 | 1292 | 0 793869 | 9 211815 | 1326 | 0 788185 | 0·005684 | 34 | 9 994316 | **23** | 45 |
| 16 | 4 | 9·206906 | 1289 | 0 793094 | 9 212611 | 1324 | 0·787389 | 0·005705 | 34 | 9 994295 | 56 | 44 |
| 17 | 8 | 9·207679 | 1287 | 0 792321 | 9 213405 | 1321 | 0·786595 | 0·005726 | 35 | 9 994274 | 52 | 43 |
| 18 | 12 | 9·208452 | 1285 | 0 791548 | 9 214198 | 1319 | 0 785802 | 0·005746 | 35 | 9 994254 | 48 | 42 |
| 19 | 16 | 9 209222 | 1282 | 0 790778 | 9 214989 | 1317 | 0 785011 | 0 005767 | 35 | 9 994233 | 44 | 41 |
| 20 | 20 | 9 209992 | 1280 | 0 790008 | 9 215780 | 1315 | 0·784220 | 0 005788 | 35 | 9 994212 | 40 | 40 |
| 21 | 24 | 9·210760 | 1278 | 0 789240 | 9 216568 | 1312 | 0 783432 | 0 005809 | 35 | 9 994191 | 36 | 39 |
| 22 | 28 | 9·211526 | 1275 | 0 788474 | 9 217356 | 1310 | 0 782644 | 0·005829 | 35 | 9 994171 | 32 | 38 |
| 23 | 32 | 9·212291 | 1273 | 0 787709 | 9 218142 | 1308 | 0 781858 | 0 005850 | 35 | 9 994150 | 28 | 37 |
| 24 | 36 | 9·213055 | 1271 | 0 786945 | 9 218926 | 1305 | 0·781074 | 0 005871 | 35 | 9 994129 | 24 | 36 |
| 25 | 40 | 9 213818 | 1268 | 0 786182 | 9 219710 | 1303 | 0·780290 | 0·005892 | 35 | 9 994108 | 20 | 35 |
| 26 | 44 | 9 214579 | 1266 | 0 785421 | 9 220492 | 1301 | 0 779508 | 0 005913 | 35 | 9 994087 | 16 | 34 |
| 27 | 48 | 9 215338 | 1264 | 0 784662 | 9 221272 | 1299 | 0·778728 | 0·005934 | 35 | 9 994066 | 12 | 33 |
| 28 | 52 | 9 216097 | 1261 | 0 783903 | 9 222052 | 1297 | 0·777948 | 0·005955 | 35 | 9 994045 | 8 | 32 |
| 29 | 56 | 9 216854 | 1259 | 0 783146 | 9 222830 | 1294 | 0·777170 | 0·005976 | 35 | 9 994024 | 4 | 31 |
| 30 | **38** | 9 217609 | 1257 | 0 782391 | 9 223607 | 1292 | 0·776393 | 0·005997 | 35 | 9 994003 | **22** | 30 |
| 31 | 4 | 9 218363 | 1255 | 0 781637 | 9·224382 | 1290 | 0·775618 | 0·006018 | 35 | 9 993982 | 56 | 29 |
| 32 | 8 | 9 219116 | 1253 | 0 780884 | 9 225156 | 1288 | 0·774844 | 0·006040 | 35 | 9·993960 | 52 | 28 |
| 33 | 12 | 9 219868 | 1250 | 0 780132 | 9 225929 | 1286 | 0·774071 | 0·006061 | 35 | 9 993939 | 48 | 27 |
| 34 | 16 | 9 220618 | 1248 | 0 779382 | 9·226700 | 1284 | 0·773300 | 0·006082 | 35 | 9 993918 | 44 | 26 |
| 35 | 20 | 9 221367 | 1246 | 0 778633 | 9 227471 | 1281 | 0·772529 | 0·006103 | 36 | 9·993897 | 40 | 25 |
| 36 | 24 | 9 222115 | 1244 | 0 777885 | 9 228239 | 1279 | 0·771761 | 0·006125 | 36 | 9 993875 | 36 | 24 |
| 37 | 28 | 9 222861 | 1242 | 0 777139 | 9 229007 | 1277 | 0·770993 | 0·006146 | 36 | 9·993854 | 32 | 23 |
| 38 | 32 | 9 223606 | 1239 | 0 776394 | 9 229773 | 1275 | 0·770227 | 0·006168 | 36 | 9·993832 | 28 | 22 |
| 39 | 36 | 9 224349 | 1237 | 0 775651 | 9·230539 | 1273 | 0·769461 | 0·006189 | 36 | 9·993811 | 24 | 21 |
| 40 | 40 | 9 225092 | 1235 | 0·774908 | 9 231302 | 1271 | 0·768698 | 0·006211 | 36 | 9 993789 | 20 | 20 |
| 41 | 44 | 9 225833 | 1233 | 0·774167 | 9 232065 | 1269 | 0·767935 | 0 006232 | 36 | 9·993768 | 16 | 19 |
| 42 | 48 | 9 226573 | 1231 | 0 773427 | 9 232826 | 1267 | 0·767174 | 0·006254 | 36 | 9 993746 | 12 | 18 |
| 43 | 52 | 9·227311 | 1228 | 0·772689 | 9 233586 | 1265 | 0·766414 | 0·006275 | 36 | 9·993725 | 8 | 17 |
| 44 | 56 | 9 228048 | 1226 | 0·771952 | 9 234345 | 1262 | 0·765655 | 0·006297 | 36 | 9·993703 | 4 | 16 |
| 45 | **39** | 9 228784 | 1224 | 0·771216 | 9 235103 | 1260 | 0·764897 | 0·006319 | 36 | 9·993681 | **21** | 15 |
| 46 | 4 | 9 229518 | 1222 | 0·770482 | 9 235859 | 1258 | 0·764141 | 0·006340 | 36 | 9 993660 | 56 | 14 |
| 47 | 8 | 9 230252 | 1220 | 0·769748 | 9 236614 | 1256 | 0·763386 | 0·006362 | 36 | 9·993638 | 52 | 13 |
| 48 | 12 | 9·230984 | 1218 | 0 769016 | 9 237368 | 1254 | 0·762632 | 0·006384 | 36 | 9·993616 | 48 | 12 |
| 49 | 16 | 9·231715 | 1216 | 0 768285 | 9 238120 | 1252 | 0·761880 | 0·006406 | 37 | 9·993594 | 44 | 11 |
| 50 | 20 | 9 232444 | 1214 | 0 767556 | 9 238872 | 1250 | 0·761128 | 0·006428 | 37 | 9·993572 | 40 | 10 |
| 51 | 24 | 9 233172 | 1212 | 0·766828 | 9 239622 | 1248 | 0·760378 | 0·006450 | 37 | 9·993550 | 36 | 9 |
| 52 | 28 | 9 233899 | 1209 | 0 766101 | 9·240371 | 1246 | 0·759629 | 0·006472 | 37 | 9·993528 | 32 | 8 |
| 53 | 32 | 9 234625 | 1207 | 0·765375 | 9 241118 | 1244 | 0·758882 | 0·006494 | 37 | 9·993506 | 28 | 7 |
| 54 | 36 | 9 235349 | 1205 | 0·764651 | 9 241865 | 1242 | 0·758135 | 0·006516 | 37 | 9·993484 | 24 | 6 |
| 55 | 40 | 9 236073 | 1203 | 0·763927 | 9 242610 | 1240 | 0·757390 | 0·006538 | 37 | 9·993462 | 20 | 5 |
| 56 | 44 | 9 236795 | 1201 | 0·763205 | 9 243354 | 1238 | 0·756646 | 0·006560 | 37 | 9·993440 | 16 | 4 |
| 57 | 48 | 9 237515 | 1199 | 0·762485 | 9 244097 | 1236 | 0·755903 | 0·006582 | 37 | 9·993418 | 12 | 3 |
| 58 | 52 | 9 238235 | 1197 | 0·761765 | 9 244839 | 1234 | 0·755161 | 0·006604 | 37 | 9·993396 | 8 | 2 |
| 59 | 56 | 9 238953 | 1195 | 0·761047 | 9 245579 | 1232 | 0·754421 | 0·006626 | 37 | 9·993374 | 4 | 1 |
| 60 | **40** | 9 239670 | | 0·760330 | 9 246319 | | 0·753681 | 0·006649 | | 9·993351 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

99° — 80°=5h 20m — 80°

## LOG. SINES, COSINES, &c.

10° 10° = 0h 40m 169°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·239670 | 1193 | 0·760330 | 9·246319 | 1230 | 0·753681 | 0·006649 | 37 | 9·993351 | 20 | 60 |
| 1 | 4 | 9·240386 | 1191 | 0·759614 | 9·247057 | 1228 | 0·752943 | 0·006671 | 37 | 9·993329 | 56 | 59 |
| 2 | 8 | 9·241101 | 1189 | 0·758899 | 9·247794 | 1226 | 0·752206 | 0·006693 | 37 | 9·993307 | 52 | 58 |
| 3 | 12 | 9·241814 | 1187 | 0·758186 | 9·248530 | 1224 | 0·751470 | 0·006716 | 37 | 9·993284 | 48 | 57 |
| 4 | 16 | 9·242526 | 1185 | 0·757474 | 9·249264 | 1222 | 0·750736 | 0·006738 | 37 | 9·993262 | 44 | 56 |
| 5 | 20 | 9·243237 | 1183 | 0·756763 | 9·249998 | 1220 | 0·750002 | 0·006760 | 37 | 9·993240 | 40 | 55 |
| 6 | 24 | 9·243947 | 1181 | 0·756053 | 9·250730 | 1218 | 0·749270 | 0·006783 | 38 | 9·993217 | 36 | 54 |
| 7 | 28 | 9·244656 | 1179 | 0·755344 | 9·251461 | 1217 | 0·748539 | 0·006805 | 38 | 9·993195 | 32 | 53 |
| 8 | 32 | 9·245363 | 1177 | 0·754637 | 9·252191 | 1215 | 0·747809 | 0·006828 | 38 | 9·993172 | 28 | 52 |
| 9 | 36 | 9·246069 | 1175 | 0·753931 | 9·252920 | 1213 | 0·747080 | 0·006851 | 38 | 9·993149 | 24 | 51 |
| 10 | 40 | 9·246775 | 1173 | 0·753225 | 9·253648 | 1211 | 0·746352 | 0·006873 | 38 | 9·993127 | 20 | 50 |
| 11 | 44 | 9·247478 | 1171 | 0·752522 | 9·254374 | 1209 | 0·745626 | 0·006896 | 38 | 9·993104 | 16 | 49 |
| 12 | 48 | 9·248181 | 1169 | 0·751819 | 9·255100 | 1207 | 0·744900 | 0·006919 | 38 | 9·993081 | 12 | 48 |
| 13 | 52 | 9·248883 | 1167 | 0·751117 | 9·255824 | 1205 | 0·744176 | 0·006941 | 38 | 9·993059 | 8 | 47 |
| 14 | 56 | 9·249583 | 1165 | 0·750417 | 9·256547 | 1203 | 0·743453 | 0·006964 | 38 | 9·993036 | 4 | 46 |
| 15 | 41 | 9·250282 | 1163 | 0·749718 | 9·257269 | 1201 | 0·742731 | 0·006987 | 38 | 9·993013 | 19 | 45 |
| 16 | 4 | 9·250980 | 1161 | 0·749020 | 9·257990 | 1200 | 0·742010 | 0·007010 | 38 | 9·992990 | 56 | 44 |
| 17 | 8 | 9·251677 | 1159 | 0·748323 | 9·258710 | 1198 | 0·741290 | 0·007033 | 38 | 9·992967 | 52 | 43 |
| 18 | 12 | 9·252373 | 1158 | 0·747627 | 9·259429 | 1196 | 0·740571 | 0·007056 | 38 | 9·992944 | 48 | 42 |
| 19 | 16 | 9·253067 | 1156 | 0·746933 | 9·260146 | 1194 | 0·739854 | 0·007079 | 38 | 9·992921 | 44 | 41 |
| 20 | 20 | 9·253761 | 1154 | 0·746239 | 9·260863 | 1192 | 0·739137 | 0·007102 | 38 | 9·992898 | 40 | 40 |
| 21 | 24 | 9·254453 | 1152 | 0·745547 | 9·261578 | 1190 | 0·738422 | 0·007125 | 38 | 9·992875 | 36 | 39 |
| 22 | 28 | 9·255144 | 1150 | 0·744856 | 9·262292 | 1189 | 0·737708 | 0·007148 | 38 | 9·992852 | 32 | 38 |
| 23 | 32 | 9·255834 | 1148 | 0·744166 | 9·263005 | 1187 | 0·736995 | 0·007171 | 39 | 9·992829 | 28 | 37 |
| 24 | 36 | 9·256523 | 1146 | 0·743477 | 9·263717 | 1185 | 0·736283 | 0·007194 | 39 | 9·992806 | 24 | 36 |
| 25 | 40 | 9·257211 | 1144 | 0·742789 | 9·264428 | 1183 | 0·735572 | 0·007217 | 39 | 9·992783 | 20 | 35 |
| 26 | 44 | 9·257898 | 1142 | 0·742102 | 9·265138 | 1181 | 0·734862 | 0·007241 | 39 | 9·992759 | 16 | 34 |
| 27 | 48 | 9·258583 | 1141 | 0·741417 | 9·265847 | 1179 | 0·734153 | 0·007264 | 39 | 9·992736 | 12 | 33 |
| 28 | 52 | 9·259268 | 1139 | 0·740732 | 9·266555 | 1178 | 0·733445 | 0·007287 | 39 | 9·992713 | 8 | 32 |
| 29 | 56 | 9·259951 | 1137 | 0·740049 | 9·267261 | 1176 | 0·732739 | 0·007310 | 39 | 9·992690 | 4 | 31 |
| 30 | 42 | 9·260633 | 1135 | 0·739367 | 9·267967 | 1174 | 0·732033 | 0·007334 | 39 | 9·992666 | 18 | 30 |
| 31 | 4 | 9·261314 | 1133 | 0·738686 | 9·268671 | 1172 | 0·731329 | 0·007357 | 39 | 9·992643 | 56 | 29 |
| 32 | 8 | 9·261994 | 1131 | 0·738006 | 9·269375 | 1170 | 0·730625 | 0·007381 | 39 | 9·992619 | 52 | 28 |
| 33 | 12 | 9·262673 | 1130 | 0·737327 | 9·270077 | 1169 | 0·729923 | 0·007404 | 39 | 9·992596 | 48 | 27 |
| 34 | 16 | 9·263351 | 1128 | 0·736649 | 9·270779 | 1167 | 0·729221 | 0·007428 | 39 | 9·992572 | 44 | 26 |
| 35 | 20 | 9·264027 | 1126 | 0·735973 | 9·271479 | 1165 | 0·728521 | 0·007451 | 39 | 9·992549 | 40 | 25 |
| 36 | 24 | 9·264703 | 1124 | 0·735297 | 9·272178 | 1164 | 0·727822 | 0·007475 | 39 | 9·992525 | 36 | 24 |
| 37 | 28 | 9·265377 | 1122 | 0·734623 | 9·272876 | 1162 | 0·727124 | 0·007499 | 39 | 9·992501 | 32 | 23 |
| 38 | 32 | 9·266051 | 1120 | 0·733949 | 9·273573 | 1160 | 0·726427 | 0·007522 | 40 | 9·992478 | 28 | 22 |
| 39 | 36 | 9·266723 | 1119 | 0·733277 | 9·274269 | 1158 | 0·725731 | 0·007546 | 40 | 9·992454 | 24 | 21 |
| 40 | 40 | 9·267395 | 1117 | 0·732605 | 9·274964 | 1157 | 0·725036 | 0·007570 | 40 | 9·992430 | 20 | 20 |
| 41 | 44 | 9·268065 | 1115 | 0·731935 | 9·275658 | 1155 | 0·724342 | 0·007594 | 40 | 9·992406 | 16 | 19 |
| 42 | 48 | 9·268734 | 1113 | 0·731266 | 9·276351 | 1153 | 0·723649 | 0·007618 | 40 | 9·992382 | 12 | 18 |
| 43 | 52 | 9·269402 | 1111 | 0·730598 | 9·277043 | 1151 | 0·722957 | 0·007641 | 40 | 9·992359 | 8 | 17 |
| 44 | 56 | 9·270069 | 1110 | 0·729931 | 9·277734 | 1150 | 0·722266 | 0·007665 | 40 | 9·992335 | 4 | 16 |
| 45 | 43 | 9·270735 | 1108 | 0·729265 | 9·278424 | 1148 | 0·721576 | 0·007689 | 40 | 9·992311 | 17 | 15 |
| 46 | 4 | 9·271400 | 1106 | 0·728600 | 9·279113 | 1147 | 0·720887 | 0·007713 | 40 | 9·992287 | 56 | 14 |
| 47 | 8 | 9·272064 | 1105 | 0·727936 | 9·279801 | 1145 | 0·720199 | 0·007737 | 40 | 9·992263 | 52 | 13 |
| 48 | 12 | 9·272726 | 1103 | 0·727274 | 9·280488 | 1143 | 0·719512 | 0·007761 | 40 | 9·992239 | 48 | 12 |
| 49 | 16 | 9·273388 | 1101 | 0·726612 | 9·281174 | 1141 | 0·718826 | 0·007786 | 40 | 9·992214 | 44 | 11 |
| 50 | 20 | 9·274049 | 1099 | 0·725951 | 9·281858 | 1140 | 0·718142 | 0·007810 | 40 | 9·992190 | 40 | 10 |
| 51 | 24 | 9·274708 | 1098 | 0·725292 | 9·282542 | 1138 | 0·717458 | 0·007834 | 40 | 9·992166 | 36 | 9 |
| 52 | 28 | 9·275367 | 1096 | 0·724633 | 9·283225 | 1136 | 0·716775 | 0·007858 | 40 | 9·992142 | 32 | 8 |
| 53 | 32 | 9·276025 | 1094 | 0·723975 | 9·283907 | 1135 | 0·716093 | 0·007882 | 41 | 9·992118 | 28 | 7 |
| 54 | 36 | 9·276681 | 1092 | 0·723319 | 9·284588 | 1133 | 0·715412 | 0·007907 | 41 | 9·992093 | 24 | 6 |
| 55 | 40 | 9·277337 | 1091 | 0·722663 | 9·285268 | 1131 | 0·714732 | 0·007931 | 41 | 9·992069 | 20 | 5 |
| 56 | 44 | 9·277991 | 1089 | 0·722009 | 9·285947 | 1130 | 0·714053 | 0·007956 | 41 | 9·992044 | 16 | 4 |
| 57 | 48 | 9·278645 | 1087 | 0·721355 | 9·286624 | 1128 | 0·713376 | 0·007980 | 41 | 9·992020 | 12 | 3 |
| 58 | 52 | 9·279297 | 1086 | 0·720703 | 9·287301 | 1126 | 0·712699 | 0·008004 | 41 | 9·991996 | 8 | 2 |
| 59 | 56 | 9·279948 | 1084 | 0·720052 | 9·287977 | 1125 | 0·712023 | 0·008029 | 41 | 9·991971 | 4 | 1 |
| 60 | 44 | 9·280599 | | 0·719401 | 9·288652 | | 0·711348 | 0·008053 | | 9·991947 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

100° 79° = 5h 16m 79°

LOG. SINES, COSINES, &c.

11° 11°=0h 44m 168°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·280599 | 1082 | 0·719401 | 9·288652 | 1123 | 0·711348 | 0·008053 | 41 | 9·991947 | **16** | 60 |
| 1 | 4 | 9·281248 | 1081 | 0·718752 | 9·289326 | 1122 | 0·710674 | 0·008078 | 41 | 9·991922 | 56 | 59 |
| 2 | 8 | 9·281897 | 1079 | 0·718103 | 9·289999 | 1120 | 0·710001 | 0·008103 | 41 | 9·991897 | 52 | 58 |
| 3 | 12 | 9·282544 | 1077 | 0·717456 | 9·290671 | 1118 | 0·709329 | 0·008127 | 41 | 9·991873 | 48 | 57 |
| 4 | 16 | 9·283190 | 1076 | 0·716810 | 9·291342 | 1117 | 0·708658 | 0·008152 | 41 | 9·991848 | 44 | 56 |
| 5 | 20 | 9·283836 | 1074 | 0·716164 | 9·292013 | 1115 | 0·707987 | 0·008177 | 41 | 9·991823 | 40 | 55 |
| 6 | 24 | 9·284480 | 1072 | 0·715520 | 9·292682 | 1114 | 0·707318 | 0·008201 | 41 | 9·991799 | 36 | 54 |
| 7 | 28 | 9·285124 | 1071 | 0·714876 | 9·293350 | 1112 | 0·706650 | 0·008226 | 42 | 9·991774 | 32 | 53 |
| 8 | 32 | 9·285766 | 1069 | 0·714234 | 9·294017 | 1111 | 0·705983 | 0·008251 | 42 | 9·991749 | 28 | 52 |
| 9 | 36 | 9·286408 | 1067 | 0·713592 | 9·294684 | 1109 | 0·705316 | 0·008276 | 42 | 9·991724 | 24 | 51 |
| 10 | 40 | 9·287048 | 1066 | 0·712952 | 9·295349 | 1107 | 0·704651 | 0·008301 | 42 | 9·991699 | 20 | 50 |
| 11 | 44 | 9·287688 | 1064 | 0·712312 | 9·296013 | 1106 | 0·703987 | 0·008326 | 42 | 9·991674 | 16 | 49 |
| 12 | 48 | 9·288326 | 1063 | 0·711674 | 9·296677 | 1104 | 0·703323 | 0·008351 | 42 | 9·991649 | 12 | 48 |
| 13 | 52 | 9·288964 | 1061 | 0·711036 | 9·297339 | 1103 | 0·702661 | 0·008376 | 42 | 9·991624 | 8 | 47 |
| 14 | 56 | 9·289600 | 1059 | 0·710400 | 9·298001 | 1101 | 0·701999 | 0·008401 | 42 | 9·991599 | 4 | 46 |
| 15 | **45** | 9·290236 | 1058 | 0·709764 | 9·298662 | 1100 | 0·701338 | 0·008426 | 42 | 9·991574 | **15** | 45 |
| 16 | 4 | 9·290870 | 1056 | 0·709130 | 9·299322 | 1098 | 0·700678 | 0·008451 | 42 | 9·991549 | 56 | 44 |
| 17 | 8 | 9·291504 | 1054 | 0·708496 | 9·299980 | 1096 | 0·700020 | 0·008476 | 42 | 9·991524 | 52 | 43 |
| 18 | 12 | 9·292137 | 1053 | 0·707863 | 9·300638 | 1095 | 0·699362 | 0·008502 | 42 | 9·991498 | 48 | 42 |
| 19 | 16 | 9·292768 | 1051 | 0·707232 | 9·301295 | 1093 | 0·698705 | 0·008527 | 42 | 9·991473 | 44 | 41 |
| 20 | 20 | 9·293399 | 1050 | 0·706601 | 9·301951 | 1092 | 0·698049 | 0·008552 | 42 | 9·991448 | 40 | 40 |
| 21 | 24 | 9·294029 | 1048 | 0·705971 | 9·302607 | 1090 | 0·697393 | 0·008578 | 42 | 9·991422 | 36 | 39 |
| 22 | 28 | 9·294658 | 1046 | 0·705342 | 9·303261 | 1089 | 0·696739 | 0·008603 | 42 | 9·991397 | 32 | 38 |
| 23 | 32 | 9·295286 | 1045 | 0·704714 | 9·303914 | 1087 | 0·696086 | 0·008628 | 43 | 9·991372 | 28 | 37 |
| 24 | 36 | 9·295913 | 1043 | 0·704087 | 9·304567 | 1086 | 0·695433 | 0·008654 | 43 | 9·991346 | 24 | 36 |
| 25 | 40 | 9·296539 | 1042 | 0·703461 | 9·305218 | 1084 | 0·694782 | 0·008679 | 43 | 9·991321 | 20 | 35 |
| 26 | 44 | 9·297164 | 1040 | 0·702836 | 9·305869 | 1083 | 0·694131 | 0·008705 | 43 | 9·991295 | 16 | 34 |
| 27 | 48 | 9·297788 | 1039 | 0·702212 | 9·306519 | 1081 | 0·693481 | 0·008730 | 43 | 9·991270 | 12 | 33 |
| 28 | 52 | 9·298412 | 1037 | 0·701588 | 9·307168 | 1080 | 0·692832 | 0·008756 | 43 | 9·991244 | 8 | 32 |
| 29 | 56 | 9·299034 | 1036 | 0·700966 | 9·307816 | 1078 | 0·692184 | 0·008782 | 43 | 9·991218 | 4 | 31 |
| 30 | **46** | 9·299655 | 1034 | 0·700345 | 9·308463 | 1077 | 0·691537 | 0·008807 | 43 | 9·991193 | **14** | 30 |
| 31 | 4 | 9·300276 | 1032 | 0·699724 | 9·309109 | 1075 | 0·690891 | 0·008833 | 43 | 9·991167 | 56 | 29 |
| 32 | 8 | 9·300895 | 1031 | 0·699105 | 9·309754 | 1074 | 0·690246 | 0·008859 | 43 | 9·991141 | 52 | 28 |
| 33 | 12 | 9·301514 | 1029 | 0·698486 | 9·310399 | 1073 | 0·689601 | 0·008885 | 43 | 9·991115 | 48 | 27 |
| 34 | 16 | 9·302132 | 1028 | 0·697868 | 9·311042 | 1071 | 0·688958 | 0·008910 | 43 | 9·991090 | 44 | 26 |
| 35 | 20 | 9·302748 | 1026 | 0·697252 | 9·311685 | 1070 | 0·688315 | 0·008936 | 43 | 9·991064 | 40 | 25 |
| 36 | 24 | 9·303364 | 1025 | 0·696636 | 9·312327 | 1068 | 0·687673 | 0·008962 | 43 | 9·991038 | 36 | 24 |
| 37 | 28 | 9·303979 | 1023 | 0·696021 | 9·312968 | 1067 | 0·687032 | 0·008988 | 43 | 9·991012 | 32 | 23 |
| 38 | 32 | 9·304593 | 1022 | 0·695407 | 9·313608 | 1065 | 0·686392 | 0·009014 | 43 | 9·990986 | 28 | 22 |
| 39 | 36 | 9·305207 | 1020 | 0·694793 | 9·314247 | 1064 | 0·685753 | 0·009040 | 43 | 9·990960 | 24 | 21 |
| 40 | 40 | 9·305819 | 1019 | 0·694181 | 9·314885 | 1062 | 0·685115 | 0·009066 | 44 | 9·990934 | 20 | 20 |
| 41 | 44 | 9·306430 | 1017 | 0·693570 | 9·315523 | 1061 | 0·684477 | 0·009092 | 44 | 9·990908 | 16 | 19 |
| 42 | 48 | 9·307041 | 1016 | 0·692959 | 9·316159 | 1060 | 0·683841 | 0·009118 | 44 | 9·990882 | 12 | 18 |
| 43 | 52 | 9·307650 | 1014 | 0·692350 | 9·316795 | 1058 | 0·683205 | 0·009145 | 44 | 9·990855 | 8 | 17 |
| 44 | 56 | 9·308259 | 1013 | 0·691741 | 9·317430 | 1057 | 0·682570 | 0·009171 | 44 | 9·990829 | 4 | 16 |
| 45 | **47** | 9·308867 | 1011 | 0·691133 | 9·318064 | 1055 | 0·681936 | 0·009197 | 44 | 9·990803 | **13** | 15 |
| 46 | 4 | 9·309474 | 1010 | 0·690526 | 9·318697 | 1054 | 0·681303 | 0·009223 | 44 | 9·990777 | 56 | 14 |
| 47 | 8 | 9·310080 | 1008 | 0·689920 | 9·319330 | 1053 | 0·680670 | 0·009250 | 44 | 9·990750 | 52 | 13 |
| 48 | 12 | 9·310685 | 1007 | 0·689315 | 9·319961 | 1051 | 0·680039 | 0·009276 | 44 | 9·990724 | 48 | 12 |
| 49 | 16 | 9·311289 | 1005 | 0·688711 | 9·320592 | 1050 | 0·679408 | 0·009303 | 44 | 9·990697 | 44 | 11 |
| 50 | 20 | 9·311893 | 1004 | 0·688107 | 9·321222 | 1048 | 0·678778 | 0·009329 | 44 | 9·990671 | 40 | 10 |
| 51 | 24 | 9·312495 | 1003 | 0·687505 | 9·321851 | 1047 | 0·678149 | 0·009355 | 44 | 9·990645 | 36 | 9 |
| 52 | 28 | 9·313097 | 1001 | 0·686903 | 9·322479 | 1045 | 0·677521 | 0·009382 | 44 | 9·990618 | 32 | 8 |
| 53 | 32 | 9·313698 | 1000 | 0·686302 | 9·323106 | 1044 | 0·676894 | 0·009409 | 44 | 9·990591 | 28 | 7 |
| 54 | 36 | 9·314297 | 998 | 0·685703 | 9·323733 | 1043 | 0·676267 | 0·009435 | 44 | 9·990565 | 24 | 6 |
| 55 | 40 | 9·314897 | 997 | 0·685103 | 9·324358 | 1041 | 0·675642 | 0·009462 | 44 | 9·990538 | 20 | 5 |
| 56 | 44 | 9·315495 | 996 | 0·684505 | 9·324983 | 1040 | 0·675017 | 0·009489 | 45 | 9·990511 | 16 | 4 |
| 57 | 48 | 9·316092 | 994 | 0·683908 | 9·325607 | 1039 | 0·674393 | 0·009515 | 45 | 9·990485 | 12 | 3 |
| 58 | 52 | 9·316689 | 993 | 0·683311 | 9·326231 | 1037 | 0·673769 | 0·009542 | 45 | 9·990458 | 8 | 2 |
| 59 | 56 | 9·317284 | 991 | 0·682716 | 9·326853 | 1036 | 0·673147 | 0·009569 | 45 | 9·990431 | 4 | 1 |
| 60 | **48** | 9·317879 | | 0·682121 | 9·327475 | | 0·672525 | 0·009596 | | 9·990404 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

101° 78°=5h 12m 78°

## LOG. SINES, COSINES, &c.

12° 12°=0h 48m 167°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·317879 | 990 | 0·682121 | 9 327475 | 1035 | 0·672525 | 0·009596 | 45 | 9·990404 | **12** | 60 |
| 1 | 4 | 9·318473 | 988 | 0·681527 | 9 328095 | 1033 | 0·671905 | 0·009622 | 45 | 9·990378 | 56 | 59 |
| 2 | 8 | 9·319066 | 987 | 0·680934 | 9 328715 | 1032 | 0·671285 | 0·009649 | 45 | 9·990351 | 52 | 58 |
| 3 | 12 | 9·319658 | 986 | 0·680342 | 9 329334 | 1030 | 0·670666 | 0·009676 | 45 | 9·990324 | 48 | 57 |
| 4 | 16 | 9·320249 | 984 | 0·679751 | 9 329953 | 1029 | 0·670047 | 0·009703 | 45 | 9·990297 | 44 | 56 |
| 5 | 20 | 9·320840 | 983 | 0·679160 | 9 330570 | 1028 | 0·669430 | 0·009730 | 45 | 9·990270 | 40 | 55 |
| 6 | 24 | 9·321430 | 982 | 0·678570 | 9 331187 | 1026 | 0·668813 | 0·009757 | 45 | 9·990243 | 36 | 54 |
| 7 | 28 | 9·322019 | 980 | 0·677981 | 9 331803 | 1025 | 0·668197 | 0·009785 | 45 | 9·990215 | 32 | 53 |
| 8 | 32 | 9·322607 | 979 | 0·677393 | 9 332418 | 1024 | 0·667582 | 0·009812 | 45 | 9·990188 | 28 | 52 |
| 9 | 36 | 9·323194 | 977 | 0·676806 | 9 333033 | 1023 | 0·666967 | 0·009839 | 45 | 9·990161 | 24 | 51 |
| 10 | 40 | 9·323780 | 976 | 0·676220 | 9·333646 | 1021 | 0·666354 | 0·009866 | 45 | 9·990134 | 20 | 50 |
| 11 | 44 | 9·324366 | 975 | 0·675634 | 9 334259 | 1020 | 0·665741 | 0·009893 | 46 | 9 990107 | 16 | 49 |
| 12 | 48 | 9·324950 | 973 | 0·675050 | 9·334871 | 1019 | 0·665129 | 0·009921 | 46 | 9 990079 | 12 | 48 |
| 13 | 52 | 9·325534 | 972 | 0·674466 | 9 335482 | 1017 | 0·664518 | 0 009948 | 46 | 9 990052 | 8 | 47 |
| 14 | 56 | 9·326117 | 970 | 0·673883 | 9 336093 | 1016 | 0·663907 | 0·009975 | 46 | 9 990025 | 4 | 46 |
| 15 | **49** | 9·326700 | 969 | 0·673300 | 9 336702 | 1015 | 0·663298 | 0·010003 | 46 | 9 989997 | **11** | 45 |
| 16 | 4 | 9·327281 | 968 | 0·672719 | 9 337311 | 1013 | 0·662689 | 0·010030 | 46 | 9 989970 | 56 | 44 |
| 17 | 8 | 9·327862 | 966 | 0·672138 | 9 337919 | 1012 | 0·662081 | 0·010058 | 46 | 9·989942 | 52 | 43 |
| 18 | 12 | 9 328442 | 965 | 0·671558 | 9 338527 | 1011 | 0 661473 | 0·010085 | 46 | 9·989915 | 48 | 42 |
| 19 | 16 | 9·329021 | 964 | 0 670979 | 9·339133 | 1010 | 0·660867 | 0·010113 | 46 | 9 989887 | 44 | 41 |
| 20 | 20 | 9 329599 | 962 | 0·670401 | 9 339739 | 1008 | 0 660261 | 0·010140 | 46 | 9 989860 | 40 | 40 |
| 21 | 24 | 9 330176 | 961 | 0·669824 | 9 340344 | 1007 | 0·659656 | 0·010168 | 46 | 9 989832 | 36 | 39 |
| 22 | 28 | 9·330753 | 960 | 0·669247 | 9 340948 | 1006 | 0·659052 | 0·010196 | 46 | 9 989804 | 32 | 38 |
| 23 | 32 | 9·331329 | 958 | 0 668671 | 9·341552 | 1004 | 0·658448 | 0·010223 | 46 | 9·989777 | 28 | 37 |
| 24 | 36 | 9 331903 | 957 | 0·668097 | 9 342155 | 1003 | 0·657845 | 0·010251 | 47 | 9·989749 | 24 | 36 |
| 25 | 40 | 9 332478 | 956 | 0·667522 | 9·342757 | 1002 | 0·657243 | 0·010279 | 47 | 9·989721 | 20 | 35 |
| 26 | 44 | 9·333051 | 954 | 0·666949 | 9·343358 | 1000 | 0·656642 | 0·010307 | 47 | 9·989693 | 16 | 34 |
| 27 | 48 | 9·333624 | 953 | 0·666376 | 9 343958 | 999 | 0 656042 | 0·010335 | 47 | 9·989665 | 12 | 33 |
| 28 | 52 | 9·334195 | 952 | 0·665805 | 9·344558 | 998 | 0·655442 | 0·010363 | 47 | 9·989637 | 8 | 32 |
| 29 | 56 | 9·334767 | 950 | 0·665233 | 9·345157 | 997 | 0·654843 | 0·010390 | 47 | 9·989610 | 4 | 31 |
| 30 | **50** | 9·335337 | 949 | 0·664663 | 9·345755 | 996 | 0·654245 | 0·010418 | 47 | 9 989582 | **10** | 30 |
| 31 | 4 | 9·335906 | 948 | 0·664094 | 9 346353 | 994 | 0·653647 | 0·010447 | 47 | 9·989553 | 56 | 29 |
| 32 | 8 | 9·336475 | 946 | 0 663525 | 9 346949 | 993 | 0·653051 | 0·010475 | 47 | 9·989525 | 52 | 28 |
| 33 | 12 | 9·337043 | 945 | 0·662957 | 9 347545 | 992 | 0 652455 | 0·010503 | 47 | 9 989497 | 48 | 27 |
| 34 | 16 | 9·337610 | 944 | 0·662390 | 9·348141 | 991 | 0·651859 | 0·010531 | 47 | 9·989469 | 44 | 26 |
| 35 | 20 | 9·338176 | 943 | 0·661824 | 9 348735 | 990 | 0·651265 | 0·010559 | 47 | 9·989441 | 40 | 25 |
| 36 | 24 | 9·338742 | 941 | 0·661258 | 9·349329 | 988 | 0·650671 | 0·010587 | 47 | 9 989413 | 36 | 24 |
| 37 | 28 | 9·339307 | 940 | 0·660693 | 9·349922 | 987 | 0·650078 | 0·010615 | 47 | 9·989385 | 32 | 23 |
| 38 | 32 | 9·339871 | 939 | 0·660129 | 9·350514 | 986 | 0·649486 | 0·010644 | 47 | 9·989356 | 28 | 22 |
| 39 | 36 | 9·340434 | 937 | 0·659566 | 9·351106 | 985 | 0·648894 | 0·010672 | 47 | 9·989328 | 24 | 21 |
| 40 | 40 | 9·340996 | 936 | 0·659004 | 9 351697 | 983 | 0·648303 | 0·010700 | 47 | 9·989300 | 20 | 20 |
| 41 | 44 | 9·341558 | 935 | 0·658442 | 9·352287 | 982 | 0·647713 | 0·010729 | 47 | 9·989271 | 16 | 19 |
| 42 | 48 | 9·342119 | 934 | 0·657881 | 9 352876 | 981 | 0·647124 | 0·010757 | 47 | 9·989243 | 12 | 18 |
| 43 | 52 | 9·342679 | 932 | 0·657321 | 9 353465 | 980 | 0 646535 | 0·010786 | 47 | 9·989214 | 8 | 17 |
| 44 | 56 | 9·343239 | 931 | 0·656761 | 9 354053 | 979 | 0·645947 | 0·010814 | 47 | 9·989186 | 4 | 16 |
| 45 | **51** | 9·343797 | 930 | 0·656203 | 9·354640 | 977 | 0 645360 | 0·010843 | 47 | 9·989157 | **9** | 15 |
| 46 | 4 | 9·344355 | 929 | 0·655645 | 9 355227 | 976 | 0·644773 | 0·010872 | 48 | 9·989128 | 56 | 14 |
| 47 | 8 | 9·344912 | 927 | 0·655088 | 9·355813 | 975 | 0·644187 | 0·010900 | 48 | 9·989100 | 52 | 13 |
| 48 | 12 | 9·345469 | 926 | 0·654531 | 9·356398 | 974 | 0·643602 | 0·010929 | 48 | 9·989071 | 48 | 12 |
| 49 | 16 | 9·346024 | 925 | 0 653976 | 9·356982 | 973 | 0·643018 | 0·010958 | 48 | 9·989042 | 44 | 11 |
| 50 | 20 | 9·346579 | 924 | 0·653421 | 9 357566 | 971 | 0·642434 | 0·010986 | 48 | 9·989014 | 40 | 10 |
| 51 | 24 | 9·347134 | 922 | 0·652866 | 9·358149 | 970 | 0·641851 | 0·011015 | 48 | 9·988985 | 36 | 9 |
| 52 | 28 | 9·347687 | 921 | 0·652313 | 9·358731 | 969 | 0·641269 | 0·011044 | 48 | 9·988956 | 32 | 8 |
| 53 | 32 | 9·348240 | 920 | 0·651760 | 9·359313 | 968 | 0·640687 | 0·011073 | 48 | 9·988927 | 28 | 7 |
| 54 | 36 | 9·348792 | 919 | 0·651208 | 9·359893 | 967 | 0·640107 | 0·011102 | 48 | 9·988898 | 24 | 6 |
| 55 | 40 | 9·349343 | 917 | 0·650657 | 9·360474 | 966 | 0·639526 | 0·011131 | 48 | 9·988869 | 20 | 5 |
| 56 | 44 | 9·349893 | 916 | 0·650107 | 9·361053 | 965 | 0·638947 | 0·011160 | 48 | 9·988840 | 16 | 4 |
| 57 | 48 | 9·350443 | 915 | 0 649557 | 9·361632 | 963 | 0·638368 | 0·011189 | 49 | 9·988811 | 12 | 3 |
| 58 | 52 | 9·350992 | 914 | 0·649008 | 9·362210 | 962 | 0·637790 | 0·011218 | 49 | 9·988782 | 8 | 2 |
| 59 | 56 | 9·351540 | 913 | 0·648460 | 9·362787 | 961 | 0·637213 | 0·011247 | 49 | 9·988753 | 4 | 1 |
| 60 | **52** | 9·352088 | | 0·647912 | 9·363364 | | 0·636636 | 0·011276 | | 9·988724 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

102° 77°=5h 8m 77°

## LOG. SINES, COSINES, &c.

13° 13°=0h 52m 166°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·352088 | 911 | 0·647912 | 9·363364 | 960 | 0·636636 | 0·011276 | 49 | 9·988724 | 8 | 60 |
| 1 | 4 | 9·352635 | 910 | 0·647365 | 9·363940 | 959 | 0·636060 | 0·011305 | 49 | 9·988695 | 56 | 59 |
| 2 | 8 | 9·353181 | 909 | 0·646819 | 9·364515 | 958 | 0·635485 | 0·011334 | 49 | 9·988666 | 52 | 58 |
| 3 | 12 | 9·353726 | 908 | 0·646274 | 9·365090 | 957 | 0·634910 | 0·011364 | 49 | 9·988636 | 48 | 57 |
| 4 | 16 | 9·354271 | 907 | 0·645729 | 9·365664 | 955 | 0·634336 | 0·011393 | 49 | 9·988607 | 44 | 56 |
| 5 | 20 | 9·354815 | 905 | 0·645185 | 9·366237 | 954 | 0·633763 | 0·011422 | 49 | 9·988578 | 40 | 55 |
| 6 | 24 | 9·355358 | 904 | 0·644642 | 9·366810 | 953 | 0·633190 | 0·011452 | 49 | 9·988548 | 36 | 54 |
| 7 | 28 | 9·355901 | 903 | 0·644099 | 9·367382 | 952 | 0·632618 | 0·011481 | 49 | 9·988519 | 32 | 53 |
| 8 | 32 | 9·356443 | 902 | 0·643557 | 9·367953 | 951 | 0·632047 | 0·011511 | 49 | 9·988489 | 28 | 52 |
| 9 | 36 | 9·356984 | 901 | 0·643016 | 9·368524 | 950 | 0·631476 | 0·011540 | 49 | 9·988460 | 24 | 51 |
| 10 | 40 | 9·357524 | 899 | 0·642476 | 9·369094 | 949 | 0·630906 | 0·011570 | 49 | 9·988430 | 20 | 50 |
| 11 | 44 | 9·358064 | 898 | 0·641936 | 9·369663 | 948 | 0·630337 | 0·011599 | 49 | 9·988401 | 16 | 49 |
| 12 | 48 | 9·358603 | 897 | 0·641397 | 9·370232 | 946 | 0·629768 | 0·011629 | 49 | 9·988371 | 12 | 48 |
| 13 | 52 | 9·359141 | 896 | 0·640859 | 9·370799 | 945 | 0·629201 | 0·011658 | 49 | 9·988342 | 8 | 47 |
| 14 | 56 | 9·359678 | 895 | 0·640322 | 9·371367 | 944 | 0·628633 | 0·011688 | 50 | 9·988312 | 4 | 46 |
| 15 | **53** | 9·360215 | 893 | 0·639785 | 9·371933 | 943 | 0·628067 | 0·011718 | 50 | 9·988282 | **7** | 45 |
| 16 | 4 | 9·360752 | 892 | 0·639248 | 9·372499 | 942 | 0·627501 | 0·011748 | 50 | 9·988252 | 56 | 44 |
| 17 | 8 | 9·361287 | 891 | 0·638713 | 9·373064 | 941 | 0·626936 | 0·011777 | 50 | 9·988223 | 52 | 43 |
| 18 | 12 | 9·361822 | 890 | 0·638178 | 9·373629 | 940 | 0·626371 | 0·011807 | 50 | 9·988193 | 48 | 42 |
| 19 | 16 | 9·362356 | 889 | 0·637644 | 9·374193 | 939 | 0·625807 | 0·011837 | 50 | 9·988163 | 44 | 41 |
| 20 | 20 | 9·362889 | 888 | 0·637111 | 9·374756 | 938 | 0·625244 | 0·011867 | 50 | 9·988133 | 40 | 40 |
| 21 | 24 | 9·363422 | 887 | 0·636578 | 9·375319 | 937 | 0·624681 | 0·011897 | 50 | 9·988103 | 36 | 39 |
| 22 | 28 | 9·363954 | 885 | 0·636046 | 9·375881 | 935 | 0·624119 | 0·011927 | 50 | 9·988073 | 32 | 38 |
| 23 | 32 | 9·364485 | 884 | 0·635515 | 9·376442 | 934 | 0·623558 | 0·011957 | 50 | 9·988043 | 28 | 37 |
| 24 | 36 | 9·365016 | 883 | 0·634984 | 9·377003 | 933 | 0·622997 | 0·011987 | 50 | 9·988013 | 24 | 36 |
| 25 | 40 | 9·365546 | 882 | 0·634454 | 9·377563 | 932 | 0·622437 | 0·012017 | 50 | 9·987983 | 20 | 35 |
| 26 | 44 | 9·366075 | 881 | 0·633925 | 9·378122 | 931 | 0·621878 | 0·012047 | 50 | 9·987953 | 16 | 34 |
| 27 | 48 | 9·366604 | 880 | 0·633396 | 9·378681 | 930 | 0·621319 | 0·012078 | 50 | 9·987922 | 12 | 33 |
| 28 | 52 | 9·367131 | 879 | 0·632869 | 9·379239 | 929 | 0·620761 | 0·012108 | 50 | 9·987892 | 8 | 32 |
| 29 | 56 | 9·367659 | 877 | 0·632341 | 9·379797 | 928 | 0·620203 | 0·012138 | 50 | 9·987862 | 4 | 31 |
| 30 | **54** | 9·368185 | 876 | 0·631815 | 9·380354 | 927 | 0·619646 | 0·012168 | 51 | 9·987832 | **6** | 30 |
| 31 | 4 | 9·368711 | 875 | 0·631289 | 9·380910 | 926 | 0·619090 | 0·012199 | 51 | 9·987801 | 56 | 29 |
| 32 | 8 | 9·369236 | 874 | 0·630764 | 9·381466 | 925 | 0·618534 | 0·012229 | 51 | 9·987771 | 52 | 28 |
| 33 | 12 | 9·369761 | 873 | 0·630239 | 9·382020 | 924 | 0·617980 | 0·012260 | 51 | 9·987740 | 48 | 27 |
| 34 | 16 | 9·370285 | 872 | 0·629715 | 9·382575 | 923 | 0·617425 | 0·012290 | 51 | 9·987710 | 44 | 26 |
| 35 | 20 | 9·370808 | 871 | 0·629192 | 9·383129 | 922 | 0·616871 | 0·012321 | 51 | 9·987679 | 40 | 25 |
| 36 | 24 | 9·371330 | 870 | 0·628670 | 9·383682 | 921 | 0·616318 | 0·012351 | 51 | 9·987649 | 36 | 24 |
| 37 | 28 | 9·371852 | 869 | 0·628148 | 9·384234 | 920 | 0·615766 | 0·012382 | 51 | 9·987618 | 32 | 23 |
| 38 | 32 | 9·372373 | 867 | 0·627627 | 9·384786 | 919 | 0·615214 | 0·012412 | 51 | 9·987588 | 28 | 22 |
| 39 | 36 | 9·372894 | 866 | 0·627106 | 9·385337 | 918 | 0·614663 | 0·012443 | 51 | 9·987557 | 24 | 21 |
| 40 | 40 | 9·373414 | 865 | 0·626586 | 9·385888 | 917 | 0·614112 | 0·012474 | 51 | 9·987526 | 20 | 20 |
| 41 | 44 | 9·373933 | 864 | 0·626067 | 9·386438 | 915 | 0·613562 | 0·012504 | 51 | 9·987496 | 16 | 19 |
| 42 | 48 | 9·374452 | 863 | 0·625548 | 9·386987 | 914 | 0·613013 | 0·012535 | 51 | 9·987465 | 12 | 18 |
| 43 | 52 | 9·374970 | 862 | 0·625030 | 9·387536 | 913 | 0·612464 | 0·012566 | 51 | 9·987434 | 8 | 17 |
| 44 | 56 | 9·375487 | 861 | 0·624513 | 9·888084 | 912 | 0·611916 | 0·012597 | 52 | 9·987403 | 4 | 16 |
| 45 | **55** | 9·376003 | 860 | 0·623997 | 9·38863i | 911 | 0·611369 | 0·012628 | 52 | 9·987372 | **5** | 15 |
| 46 | 4 | 9·376519 | 859 | 0·623481 | 9·389178 | 910 | 0·610822 | 0·012659 | 52 | 9·987341 | 56 | 14 |
| 47 | 8 | 9·377035 | 858 | 0·622965 | 9·389724 | 909 | 0·610276 | 0·012690 | 52 | 9·987310 | 52 | 13 |
| 48 | 12 | 9·377549 | 857 | 0·622451 | 9·390270 | 908 | 0·609730 | 0·012721 | 52 | 9·987279 | 48 | 12 |
| 49 | 16 | 9·378063 | 856 | 0·621937 | 9·390815 | 907 | 0·609185 | 0·012752 | 52 | 9·987248 | 44 | 11 |
| 50 | 20 | 9·378577 | 854 | 0·621423 | 9·391360 | 906 | 0·608640 | 0·012783 | 52 | 9·987217 | 40 | 10 |
| 51 | 24 | 9·379089 | 853 | 0·620911 | 9·391903 | 905 | 0·608097 | 0·012814 | 52 | 9·987186 | 36 | 9 |
| 52 | 28 | 9·379601 | 852 | 0·620399 | 9·392447 | 904 | 0·607553 | 0·012845 | 52 | 9·987155 | 32 | 8 |
| 53 | 32 | 9·380113 | 851 | 0·619887 | 9·392989 | 903 | 0·607011 | 0·012876 | 52 | 9·987124 | 28 | 7 |
| 54 | 36 | 9·380624 | 850 | 0·619376 | 9·393531 | 902 | 0·606469 | 0·012908 | 52 | 9·987092 | 24 | 6 |
| 55 | 40 | 9·381134 | 849 | 0·618866 | 9·394073 | 901 | 0·605927 | 0·012939 | 52 | 9·987061 | 20 | 5 |
| 56 | 44 | 9·381643 | 848 | 0·618357 | 9·394614 | 900 | 0·605386 | 0·012970 | 52 | 9·987030 | 16 | 4 |
| 57 | 48 | 9·382152 | 847 | 0·617848 | 9·395154 | 899 | 0·604846 | 0·013002 | 52 | 9·986998 | 12 | 3 |
| 58 | 52 | 9·382661 | 846 | 0·617339 | 9·395694 | 898 | 0·604306 | 0·013033 | 52 | 9·986967 | 8 | 2 |
| 59 | 56 | 9·383168 | 845 | 0·616832 | 9·396233 | 897 | 0·603767 | 0·013064 | 52 | 9·986936 | 4 | 1 |
| 60 | **56** | 9·383675 | | 0·616325 | 9·396771 | | 0·603229 | 0·013096 | | 9·986904 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

103° 76°=5h 4m 76°

## LOG. SINES, COSINES, &c.

14° 14°=0h 56m 165°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·383675 | 844 | 0·616325 | 9·396771 | 896 | 0·603229 | 0·013096 | 52 | 9·986904 | 4 | 60 |
| 1 | 4 | 9·384182 | 843 | 0·615818 | 9·397309 | 896 | 0·602691 | 0·013127 | 53 | 9·986873 | 56 | 59 |
| 2 | 8 | 9·384687 | 842 | 0·615313 | 9·397846 | 895 | 0·602154 | 0·013159 | 53 | 9·986841 | 52 | 58 |
| 3 | 12 | 9·385192 | 841 | 0·614808 | 9·398383 | 894 | 0·601617 | 0·013191 | 53 | 9·986809 | 48 | 57 |
| 4 | 16 | 9·385697 | 840 | 0·614303 | 9·398919 | 893 | 0·601081 | 0·013222 | 53 | 9·986778 | 44 | 56 |
| 5 | 20 | 9·386201 | 839 | 0·613799 | 9·399455 | 892 | 0·600545 | 0·013254 | 53 | 9·986746 | 40 | 55 |
| 6 | 24 | 9·386704 | 838 | 0·613296 | 9·399990 | 891 | 0·600010 | 0·013286 | 53 | 9·986714 | 36 | 54 |
| 7 | 28 | 9·387207 | 837 | 0·612793 | 9·400524 | 890 | 0·599476 | 0·013317 | 53 | 9·986683 | 32 | 53 |
| 8 | 32 | 9·387709 | 836 | 0·612291 | 9·401058 | 889 | 0·598942 | 0·013349 | 53 | 9·986651 | 28 | 52 |
| 9 | 36 | 9·388210 | 835 | 0·611790 | 9·401591 | 888 | 0·598409 | 0·013381 | 53 | 9·986619 | 24 | 51 |
| 10 | 40 | 9·388711 | 834 | 0·611289 | 9·402124 | 887 | 0·597876 | 0·013413 | 53 | 9·986587 | 20 | 50 |
| 11 | 44 | 9·389211 | 833 | 0·610789 | 9·402656 | 886 | 0·597344 | 0·013445 | 53 | 9·986555 | 16 | 49 |
| 12 | 48 | 9·389711 | 832 | 0·610289 | 9·403187 | 885 | 0·596813 | 0·013477 | 53 | 9·986523 | 12 | 48 |
| 13 | 52 | 9·390210 | 831 | 0·609790 | 9·403718 | 884 | 0·596282 | 0·013509 | 53 | 9·986491 | 8 | 47 |
| 14 | 56 | 9·390708 | 830 | 0·609292 | 9·404249 | 883 | 0·595751 | 0·013541 | 53 | 9·986459 | 4 | 46 |
| 15 | **57** | 9·391206 | 828 | 0·608794 | 9·404778 | 882 | 0·595222 | 0·013573 | 53 | 9·986427 | **3** | 45 |
| 16 | 4 | 9·391703 | 827 | 0·608297 | 9·405308 | 881 | 0·594692 | 0·013605 | 53 | 9·986395 | 56 | 44 |
| 17 | 8 | 9·392199 | 826 | 0·607801 | 9·405836 | 880 | 0·594164 | 0·013637 | 54 | 9·986363 | 52 | 43 |
| 18 | 12 | 9·392695 | 825 | 0·607305 | 9·406364 | 879 | 0·593636 | 0·013669 | 54 | 9·986331 | 48 | 42 |
| 19 | 16 | 9·393191 | 824 | 0·606809 | 9·406892 | 878 | 0·593108 | 0·013701 | 54 | 9·986299 | 44 | 41 |
| 20 | 20 | 9·393685 | 823 | 0·606315 | 9·407419 | 877 | 0·592581 | 0·013734 | 54 | 9·986266 | 40 | 40 |
| 21 | 24 | 9·394179 | 822 | 0·605821 | 9·407945 | 876 | 0·592055 | 0·013766 | 54 | 9·986234 | 36 | 39 |
| 22 | 28 | 9·394673 | 821 | 0·605327 | 9·408471 | 875 | 0·591529 | 0·013798 | 54 | 9·986202 | 32 | 38 |
| 23 | 32 | 9·395166 | 820 | 0·604834 | 9·408996 | 874 | 0·591004 | 0·013831 | 54 | 9·986169 | 28 | 37 |
| 24 | 36 | 9·395658 | 819 | 0·604342 | 9·409521 | 874 | 0·590479 | 0·013863 | 54 | 9·986137 | 24 | 36 |
| 25 | 40 | 9·396150 | 818 | 0·603850 | 9·410045 | 873 | 0·589955 | 0·013896 | 54 | 9·986104 | 20 | 35 |
| 26 | 44 | 9·396641 | 817 | 0·603359 | 9·410569 | 872 | 0·589431 | 0·013928 | 54 | 9·986072 | 16 | 34 |
| 27 | 48 | 9·397132 | 817 | 0·602868 | 9·411092 | 871 | 0·588908 | 0·013961 | 54 | 9·986039 | 12 | 33 |
| 28 | 52 | 9·397621 | 816 | 0·602379 | 9·411615 | 870 | 0·588385 | 0·013993 | 54 | 9·986007 | 8 | 32 |
| 29 | 56 | 9·398111 | 815 | 0·601889 | 9·412137 | 869 | 0·587863 | 0·014026 | 54 | 9·985974 | 4 | 31 |
| 30 | **58** | 9·398600 | 814 | 0·601400 | 9·412658 | 868 | 0·587342 | 0·014058 | 54 | 9·985942 | **2** | 30 |
| 31 | 4 | 9·399088 | 813 | 0·600912 | 9·413179 | 867 | 0·586821 | 0·014091 | 55 | 9·985909 | 56 | 29 |
| 32 | 8 | 9·399575 | 812 | 0·600425 | 9·413699 | 866 | 0·586301 | 0·014124 | 55 | 9·985876 | 52 | 28 |
| 33 | 12 | 9·400062 | 811 | 0·599938 | 9·414219 | 865 | 0·585781 | 0·014157 | 55 | 9·985843 | 48 | 27 |
| 34 | 16 | 9·400549 | 810 | 0·599451 | 9·414738 | 864 | 0·585262 | 0·014189 | 55 | 9·985811 | 44 | 26 |
| 35 | 20 | 9·401035 | 809 | 0·598965 | 9·415257 | 864 | 0·584743 | 0·014222 | 55 | 9·985778 | 40 | 25 |
| 36 | 24 | 9·401520 | 808 | 0·598480 | 9·415775 | 863 | 0·584225 | 0·014255 | 55 | 9·985745 | 36 | 24 |
| 37 | 28 | 9·402005 | 807 | 0·597995 | 9·416293 | 862 | 0·583707 | 0·014288 | 55 | 9·985712 | 32 | 23 |
| 38 | 32 | 9·402489 | 806 | 0·597511 | 9·416810 | 861 | 0·583190 | 0·014321 | 55 | 9·985679 | 28 | 22 |
| 39 | 36 | 9·402972 | 805 | 0·597028 | 9·417326 | 860 | 0·582674 | 0·014354 | 55 | 9·985646 | 24 | 21 |
| 40 | 40 | 9·403455 | 804 | 0·596545 | 9·417842 | 859 | 0·582158 | 0·014387 | 55 | 9·985613 | 20 | 20 |
| 41 | 44 | 9·403938 | 803 | 0·596062 | 9·418358 | 858 | 0·581642 | 0·014420 | 55 | 9·985580 | 16 | 19 |
| 42 | 48 | 9·404420 | 802 | 0·595580 | 9·418873 | 857 | 0·581127 | 0·014453 | 55 | 9·985547 | 12 | 18 |
| 43 | 52 | 9·404901 | 801 | 0·595099 | 9·419387 | 856 | 0·580613 | 0·014486 | 55 | 9·985514 | 8 | 17 |
| 44 | 56 | 9·405382 | 800 | 0·594618 | 9·419901 | 855 | 0·580099 | 0·014520 | 55 | 9·985480 | 4 | 16 |
| 45 | **59** | 9·405862 | 799 | 0·594138 | 9·420415 | 855 | 0·579585 | 0·014553 | 55 | 9·985447 | **1** | 15 |
| 46 | 4 | 9·406341 | 798 | 0·593659 | 9·420927 | 854 | 0·579073 | 0·014586 | 56 | 9·985414 | 56 | 14 |
| 47 | 8 | 9·406820 | 797 | 0·593180 | 9·421440 | 853 | 0·578560 | 0·014619 | 56 | 9·985381 | 52 | 13 |
| 48 | 12 | 9·407299 | 796 | 0·592701 | 9·421952 | 852 | 0·578048 | 0·014653 | 56 | 9·985347 | 48 | 12 |
| 49 | 16 | 9·407777 | 795 | 0·592223 | 9·422463 | 851 | 0·577537 | 0·014686 | 56 | 9·985314 | 44 | 11 |
| 50 | 20 | 9·408254 | 794 | 0·591746 | 9·422974 | 850 | 0·577026 | 0·014720 | 56 | 9·985280 | 40 | 10 |
| 51 | 24 | 9·408731 | 794 | 0·591269 | 9·423484 | 849 | 0·576516 | 0·014753 | 56 | 9·985247 | 36 | 9 |
| 52 | 28 | 9·409207 | 793 | 0·590793 | 9·423993 | 848 | 0·576007 | 0·014787 | 56 | 9·985213 | 32 | 8 |
| 53 | 32 | 9·409682 | 792 | 0·590318 | 9·424503 | 848 | 0·575497 | 0·014820 | 56 | 9·985180 | 28 | 7 |
| 54 | 36 | 9·410157 | 791 | 0·589843 | 9·425011 | 847 | 0·574989 | 0·014854 | 56 | 9·985146 | 24 | 6 |
| 55 | 40 | 9·410632 | 790 | 0·589368 | 9·425519 | 846 | 0·574481 | 0·014887 | 56 | 9·985113 | 20 | 5 |
| 56 | 44 | 9·411106 | 789 | 0·588894 | 9·426027 | 845 | 0·573973 | 0·014921 | 56 | 9·985079 | 16 | 4 |
| 57 | 48 | 9·411579 | 788 | 0·588421 | 9·426534 | 844 | 0·573466 | 0·014955 | 56 | 9·985045 | 12 | 3 |
| 58 | 52 | 9·412052 | 787 | 0·587948 | 9·427041 | 843 | 0·572959 | 0·014989 | 56 | 9·985011 | 8 | 2 |
| 59 | 56 | 9·412524 | 786 | 0·587476 | 9·427547 | 843 | 0·572453 | 0·015022 | 56 | 9·984978 | 4 | 1 |
| 60 | **60** | 9·412996 | | 0·587004 | 9·428052 | | 0·571948 | 0·015056 | | 9·984944 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

104° 75°=5h 0m 75°

## LOG. SINES, COSINES, &c.

15° | 15° = 1h 0m | 164°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·412996 | 785 | 0·587004 | 9·428052 | 842 | 0·571948 | 0·015056 | 57 | 9·984944 | **60** | 60 |
| 1 | 4 | 9·413467 | 784 | 0·586533 | 9·428558 | 841 | 0·571442 | 0·015090 | 57 | 9·984910 | 56 | 59 |
| 2 | 8 | 9·413938 | 783 | 0·586062 | 9·429062 | 840 | 0·570938 | 0·015124 | 57 | 9·984876 | 52 | 58 |
| 3 | 12 | 9·414408 | 783 | 0·585592 | 9·429566 | 839 | 0·570434 | 0·015158 | 57 | 9·984842 | 48 | 57 |
| 4 | 16 | 9·414878 | 782 | 0·585122 | 9·430070 | 838 | 0·569930 | 0·015192 | 57 | 9·984808 | 44 | 56 |
| 5 | 20 | 9·415347 | 781 | 0·584653 | 9·430573 | 838 | 0·569427 | 0·015226 | 57 | 9·984774 | 40 | 55 |
| 6 | 24 | 9·415815 | 780 | 0·584185 | 9·431075 | 837 | 0·568925 | 0·015260 | 57 | 9·984740 | 36 | 54 |
| 7 | 28 | 9·416283 | 779 | 0·583717 | 9·431577 | 836 | 0·568423 | 0·015294 | 57 | 9·984706 | 32 | 53 |
| 8 | 32 | 9·416751 | 778 | 0·583249 | 9·432079 | 835 | 0·567921 | 0·015328 | 57 | 9·984672 | 28 | 52 |
| 9 | 36 | 9·417217 | 777 | 0·582783 | 9·432580 | 834 | 0·567420 | 0·015362 | 57 | 9·984638 | 24 | 51 |
| 10 | 40 | 9·417684 | 776 | 0·582316 | 9·433080 | 833 | 0·566920 | 0·015397 | 57 | 9·984603 | 20 | 50 |
| 11 | 44 | 9·418150 | 775 | 0·581850 | 9·433580 | 832 | 0·566420 | 0·015431 | 57 | 9·984569 | 16 | 49 |
| 12 | 48 | 9·418615 | 774 | 0·581385 | 9·434080 | 832 | 0·565920 | 0·015465 | 57 | 9·984535 | 12 | 48 |
| 13 | 52 | 9·419079 | 773 | 0·580921 | 9·434579 | 831 | 0·565421 | 0·015500 | 57 | 9·984500 | 8 | 47 |
| 14 | 56 | 9·419544 | 773 | 0·580456 | 9·435078 | 830 | 0·564922 | 0·015534 | 57 | 9·984466 | 4 | 46 |
| 15 | **1** | 9·420007 | 772 | 0·579993 | 9·435576 | 829 | 0·564424 | 0·015568 | 58 | 9·984432 | **59** | 45 |
| 16 | 4 | 9·420470 | 771 | 0·579530 | 9·436073 | 828 | 0·563927 | 0·015603 | 58 | 9·984397 | 56 | 44 |
| 17 | 8 | 9·420933 | 770 | 0·579067 | 9·436570 | 828 | 0·563430 | 0·015637 | 58 | 9·984363 | 52 | 43 |
| 18 | 12 | 9·421395 | 769 | 0·578605 | 9·437067 | 827 | 0·562933 | 0·015672 | 58 | 9·984328 | 48 | 42 |
| 19 | 16 | 9·421857 | 768 | 0·578143 | 9·437563 | 826 | 0·562437 | 0·015706 | 58 | 9·984294 | 44 | 41 |
| 20 | 20 | 9·422318 | 767 | 0·577682 | 9·438059 | 825 | 0·561941 | 0·015741 | 58 | 9·984259 | 40 | 40 |
| 21 | 24 | 9·422778 | 767 | 0·577222 | 9·438554 | 824 | 0·561446 | 0·015776 | 58 | 9·984224 | 36 | 39 |
| 22 | 28 | 9·423238 | 766 | 0·576762 | 9·439048 | 823 | 0·560952 | 0·015810 | 58 | 9·984190 | 32 | 38 |
| 23 | 32 | 9·423697 | 765 | 0·576303 | 9·439543 | 823 | 0·560457 | 0·015845 | 58 | 9·984155 | 28 | 37 |
| 24 | 36 | 9·424156 | 764 | 0·575844 | 9·440036 | 822 | 0·559964 | 0·015880 | 58 | 9·984120 | 24 | 36 |
| 25 | 40 | 9·424615 | 763 | 0·575385 | 9·440529 | 821 | 0·559471 | 0·015915 | 58 | 9·984085 | 20 | 35 |
| 26 | 44 | 9·425073 | 762 | 0·574927 | 9·441022 | 820 | 0·558978 | 0·015950 | 58 | 9·984050 | 16 | 34 |
| 27 | 48 | 9·425530 | 761 | 0·574470 | 9·441514 | 819 | 0·558486 | 0·015985 | 58 | 9·984015 | 12 | 33 |
| 28 | 52 | 9·425987 | 760 | 0·574013 | 9·442006 | 819 | 0·557994 | 0·016019 | 58 | 9·983981 | 8 | 32 |
| 29 | 56 | 9·426443 | 760 | 0·573557 | 9·442497 | 818 | 0·557503 | 0·016054 | 58 | 9·983946 | 4 | 31 |
| 30 | **2** | 9·426899 | 759 | 0·573101 | 9·442988 | 817 | 0·557012 | 0·016089 | 58 | 9·983911 | **58** | 30 |
| 31 | 4 | 9·427354 | 758 | 0·572646 | 9·443479 | 816 | 0·556521 | 0·016125 | 58 | 9·983875 | 56 | 29 |
| 32 | 8 | 9·427809 | 757 | 0·572191 | 9·443968 | 816 | 0·556032 | 0·016160 | 59 | 9·983840 | 52 | 28 |
| 33 | 12 | 9·428263 | 756 | 0·571737 | 9·444458 | 815 | 0·555542 | 0·016195 | 59 | 9·983805 | 48 | 27 |
| 34 | 16 | 9·428717 | 755 | 0·571283 | 9·444947 | 814 | 0·555053 | 0·016230 | 59 | 9·983770 | 44 | 26 |
| 35 | 20 | 9·429170 | 754 | 0·570830 | 9·445435 | 813 | 0·554565 | 0·016265 | 59 | 9·983735 | 40 | 25 |
| 36 | 24 | 9·429623 | 753 | 0·570377 | 9·445923 | 812 | 0·554077 | 0·016300 | 59 | 9·983700 | 36 | 24 |
| 37 | 28 | 9·430075 | 752 | 0·569925 | 9·446411 | 812 | 0·553589 | 0·016336 | 59 | 9·983664 | 32 | 23 |
| 38 | 32 | 9·430527 | 752 | 0·569473 | 9·446898 | 811 | 0·553102 | 0·016371 | 59 | 9·983629 | 28 | 22 |
| 39 | 36 | 9·430978 | 751 | 0·569022 | 9·447384 | 810 | 0·552616 | 0·016406 | 59 | 9·983594 | 24 | 21 |
| 40 | 40 | 9·431429 | 750 | 0·568571 | 9·447870 | 809 | 0·552130 | 0·016442 | 59 | 9·983558 | 20 | 20 |
| 41 | 44 | 9·431879 | 749 | 0·568121 | 9·448356 | 809 | 0·551644 | 0·016477 | 59 | 9·983523 | 16 | 19 |
| 42 | 48 | 9·432329 | 749 | 0·567671 | 9·448841 | 808 | 0·551159 | 0·016513 | 59 | 9·983487 | 12 | 18 |
| 43 | 52 | 9·432778 | 748 | 0·567222 | 9·449326 | 807 | 0·550674 | 0·016548 | 59 | 9·983452 | 8 | 17 |
| 44 | 56 | 9·433226 | 747 | 0·566774 | 9·449810 | 806 | 0·550190 | 0·016584 | 59 | 9·983416 | 4 | 16 |
| 45 | **3** | 9·433675 | 746 | 0·566325 | 9·450294 | 806 | 0·549706 | 0·016619 | 59 | 9·983381 | **57** | 15 |
| 46 | 4 | 9·434122 | 745 | 0·565878 | 9·450777 | 805 | 0·549223 | 0·016655 | 59 | 9·983345 | 56 | 14 |
| 47 | 8 | 9·434569 | 744 | 0·565431 | 9·451260 | 804 | 0·548740 | 0·016691 | 59 | 9·983309 | 52 | 13 |
| 48 | 12 | 9·435016 | 744 | 0·564984 | 9·451743 | 803 | 0·548257 | 0·016727 | 60 | 9·983273 | 48 | 12 |
| 49 | 16 | 9·435462 | 743 | 0·564538 | 9·452225 | 802 | 0·547775 | 0·016762 | 60 | 9·983238 | 44 | 11 |
| 50 | 20 | 9·435908 | 742 | 0·564092 | 9·452706 | 802 | 0·547294 | 0·016798 | 60 | 9·983202 | 40 | 10 |
| 51 | 24 | 9·436353 | 741 | 0·563647 | 9·453187 | 801 | 0·546813 | 0·016834 | 60 | 9·983166 | 36 | 9 |
| 52 | 28 | 9·436798 | 740 | 0·563202 | 9·453668 | 800 | 0·546332 | 0·016870 | 60 | 9·983130 | 32 | 8 |
| 53 | 32 | 9·437242 | 740 | 0·562758 | 9·454148 | 799 | 0·545852 | 0·016906 | 60 | 9·983094 | 28 | 7 |
| 54 | 36 | 9·437686 | 739 | 0·562314 | 9·454628 | 799 | 0·545372 | 0·016942 | 60 | 9·983058 | 24 | 6 |
| 55 | 40 | 9·438129 | 738 | 0·561871 | 9·455107 | 798 | 0·544893 | 0·016978 | 60 | 9·983022 | 20 | 5 |
| 56 | 44 | 9·438572 | 737 | 0·561428 | 9·455586 | 797 | 0·544414 | 0·017014 | 60 | 9·982986 | 16 | 4 |
| 57 | 48 | 9·439014 | 736 | 0·560986 | 9·456064 | 796 | 0·543936 | 0·017050 | 60 | 9·982950 | 12 | 3 |
| 58 | 52 | 9·439456 | 736 | 0·560544 | 9·456542 | 796 | 0·543458 | 0·017086 | 60 | 9·982914 | 8 | 2 |
| 59 | 56 | 9·439897 | 735 | 0·560103 | 9·457019 | 795 | 0·542981 | 0·017122 | 60 | 9·982878 | 4 | 1 |
| 60 | **4** | 9·440338 | | 0·559662 | 9·457496 | | 0·542504 | 0·017158 | | 9·982842 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. S. | ′ |

105° | 74° = 4h 56m | 74°

## LOG. SINES, COSINES, &c.

16° 16° = 1h 4m 163°

| ′ | M. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s. | | | | | | | | | | | |
| 0 | 0 | 9·440338 | 734 | 0·559662 | 9·457496 | 794 | 0·542504 | 0·017158 | 60 | 9·982842 | **56** | 60 |
| 1 | 4 | 9·440778 | 733 | 0·559222 | 9 457973 | 793 | 0·542027 | 0·017195 | 60 | 9 982805 | 56 | 59 |
| 2 | 8 | 9·441218 | 732 | 0·558782 | 9 458449 | 793 | 0·541551 | 0·017231 | 61 | 9 982769 | 52 | 58 |
| 3 | 12 | 9·441658 | 731 | 0·558342 | 9 458925 | 792 | 0·541075 | 0·017267 | 61 | 9 982733 | 48 | 57 |
| 4 | 16 | 9·442096 | 731 | 0·557904 | 9 459400 | 791 | 0·540600 | 0·017304 | 61 | 9 982696 | 44 | 56 |
| 5 | 20 | 9·442535 | 730 | 0·557465 | 9 459875 | 790 | 0·540125 | 0·017340 | 61 | 9 982660 | 40 | 55 |
| 6 | 24 | 9·442973 | 729 | 0·557027 | 9 460349 | 790 | 0·539651 | 0·017376 | 61 | 9 982624 | 36 | 54 |
| 7 | 28 | 9·443410 | 728 | 0·556590 | 9 460823 | 789 | 0·539177 | 0·017413 | 61 | 9 982587 | 32 | 53 |
| 8 | 32 | 9·443847 | 727 | 0·556153 | 9 461297 | 788 | 0·538703 | 0·017449 | 61 | 9 982551 | 28 | 52 |
| 9 | 36 | 9·444284 | 727 | 0·555716 | 9 461770 | 788 | 0·538230 | 0·017486 | 61 | 9 982514 | 24 | 51 |
| 10 | 40 | 9·444720 | 726 | 0·555280 | 9 462242 | 787 | 0·537758 | 0·017523 | 61 | 9 982477 | 20 | 50 |
| 11 | 44 | 9·445155 | 725 | 0·554845 | 9 462715 | 786 | 0·537285 | 0·017559 | 61 | 9 982441 | 16 | 49 |
| 12 | 48 | 9·445590 | 724 | 0·554410 | 9 463186 | 785 | 0·536814 | 0 017596 | 61 | 9 982404 | 12 | 48 |
| 13 | 52 | 9 446025 | 723 | 0·553975 | 9 463658 | 785 | 0·536342 | 0 017633 | 61 | 9 982367 | 8 | 47 |
| 14 | 56 | 9·446459 | 723 | 0·553541 | 9 464128 | 784 | 0·535872 | 0·017669 | 61 | 9 982331 | 4 | 46 |
| 15 | **5** | 9·446893 | 722 | 0·553107 | 9 464599 | 783 | 0·535401 | 0 017706 | 61 | 9 982294 | **55** | 45 |
| 16 | 4 | 9·447326 | 721 | 0·552674 | 9 465069 | 783 | 0 534931 | 0·017743 | 61 | 9 982257 | 56 | 44 |
| 17 | 8 | 9·447759 | 720 | 0·552241 | 9 465539 | 782 | 0·534461 | 0·017780 | 62 | 9 982220 | 52 | 43 |
| 18 | 12 | 9·448191 | 720 | 0·551809 | 9 466008 | 781 | 0 533992 | 0 017817 | 62 | 9 982183 | 48 | 42 |
| 19 | 16 | 9·448623 | 719 | 0·551377 | 9·466477 | 780 | 0 533523 | 0·017854 | 62 | 9 982146 | 44 | 41 |
| 20 | 20 | 9·449054 | 718 | 0·550946 | 9 466945 | 780 | 0 533055 | 0·017891 | 62 | 9 982109 | 40 | 40 |
| 21 | 24 | 9·449485 | 717 | 0·550515 | 9·467413 | 779 | 0·532587 | 0·017928 | 62 | 9·982072 | 36 | 39 |
| 22 | 28 | 9·449915 | 716 | 0·550085 | 9·467880 | 778 | 0·532120 | 0 017965 | 62 | 9·982035 | 32 | 38 |
| 23 | 32 | 9·450345 | 716 | 0·549655 | 9 468347 | 778 | 0·531653 | 0·018002 | 62 | 9·981998 | 28 | 37 |
| 24 | 36 | 9·450775 | 715 | 0·549225 | 9·468814 | 777 | 0·531186 | 0 018039 | 62 | 9·981961 | 24 | 36 |
| 25 | 40 | 9·451204 | 714 | 0·548796 | 9·469280 | 776 | 0·530720 | 0·018076 | 62 | 9·981924 | 20 | 35 |
| 26 | 44 | 9·451632 | 713 | 0·548368 | 9·469746 | 775 | 0·530254 | 0·018114 | 62 | 9·981886 | 16 | 34 |
| 27 | 48 | 9·452060 | 713 | 0·547940 | 9·470211 | 775 | 0·529789 | 0·018151 | 62 | 9·981849 | 12 | 33 |
| 28 | 52 | 9·452488 | 712 | 0·547512 | 9·470676 | 774 | 0·529324 | 0 018188 | 62 | 9 981812 | 8 | 32 |
| 29 | 56 | 9·452915 | 711 | 0·547085 | 9·471141 | 773 | 0·528859 | 0·018226 | 62 | 9·981774 | 4 | 31 |
| 30 | **6** | 9·453342 | 710 | 0·546658 | 9·471605 | 773 | 0·528395 | 0·018263 | 62 | 9 981737 | **54** | 30 |
| 31 | 4 | 9·453768 | 710 | 0·546232 | 9·472069 | 772 | 0·527931 | 0·018300 | 63 | 9·981700 | 56 | 29 |
| 32 | 8 | 9·454194 | 709 | 0·545806 | 9·472532 | 771 | 0·527468 | 0·018338 | 63 | 9·981662 | 52 | 28 |
| 33 | 12 | 9·454619 | 708 | 0·545381 | 9·472995 | 771 | 0 527005 | 0·018375 | 63 | 9·981625 | 48 | 27 |
| 34 | 16 | 9·455044 | 707 | 0·544956 | 9·473457 | 770 | 0·526543 | 0·018413 | 63 | 9·981587 | 44 | 26 |
| 35 | 20 | 9·455469 | 707 | 0·544531 | 9·473919 | 769 | 0·526081 | 0·018451 | 63 | 9·981549 | 40 | 25 |
| 36 | 24 | 9·455893 | 706 | 0·544107 | 9·474381 | 769 | 0·525619 | 0·018488 | 63 | 9·981512 | 36 | 24 |
| 37 | 28 | 9·456316 | 705 | 0·543684 | 9·474842 | 768 | 0·525158 | 0·018526 | 63 | 9·981474 | 32 | 23 |
| 38 | 32 | 9·456739 | 704 | 0·543261 | 9·475303 | 767 | 0·524697 | 0·018564 | 63 | 9·981436 | 28 | 22 |
| 39 | 36 | 9·457162 | 704 | 0·542838 | 9·475763 | 767 | 0·524237 | 0·018601 | 63 | 9 98.399 | 24 | 21 |
| 40 | 40 | 9·457584 | 703 | 0·542416 | 9·476223 | 766 | 0·523777 | 0·018639 | 63 | 9·981361 | 20 | 20 |
| 41 | 44 | 9·458006 | 702 | 0·541994 | 9·476683 | 765 | 0·523317 | 0·018677 | 63 | 9·981323 | 16 | 19 |
| 42 | 48 | 9·458427 | 701 | 0·541573 | 9·477142 | 765 | 0·522858 | 0·018715 | 63 | 9·981285 | 12 | 18 |
| 43 | 52 | 9·458848 | 701 | 0·541152 | 9·477601 | 764 | 0·522399 | 0·018753 | 63 | 9·981247 | 8 | 17 |
| 44 | 56 | 9·459268 | 700 | 0·540732 | 9·478059 | 763 | 0·521941 | 0·018791 | 63 | 9·981209 | 4 | 16 |
| 45 | **7** | 9·459688 | 699 | 0·540312 | 9·478517 | 763 | 0·521483 | 0·018829 | 63 | 9·981171 | **53** | 15 |
| 46 | 4 | 9·460108 | 698 | 0·539892 | 9·478975 | 762 | 0·521025 | 0·018867 | 64 | 9·981133 | 56 | 14 |
| 47 | 8 | 9·460527 | 698 | 0·539473 | 9·479432 | 761 | 0·520568 | 0·018905 | 64 | 9·981095 | 52 | 13 |
| 48 | 12 | 9·460946 | 697 | 0·539054 | 9·479889 | 761 | 0·520111 | 0·018943 | 64 | 9·981057 | 48 | 12 |
| 49 | 16 | 9·461364 | 696 | 0·538636 | 9·480345 | 760 | 0·519655 | 0·018981 | 64 | 9·981019 | 44 | 11 |
| 50 | 20 | 9·461782 | 695 | 0·538218 | 9·480801 | 759 | 0·519199 | 0·019019 | 64 | 9·980981 | 40 | 10 |
| 51 | 24 | 9·462199 | 695 | 0·537801 | 9·481257 | 759 | 0·518743 | 0·019058 | 64 | 9 980942 | 36 | 9 |
| 52 | 28 | 9·462616 | 694 | 0·537384 | 9·481712 | 758 | 0·518288 | 0·019096 | 64 | 9·980904 | 32 | 8 |
| 53 | 32 | 9·463032 | 693 | 0·536968 | 9·482167 | 757 | 0·517833 | 0·019134 | 64 | 9·980866 | 28 | 7 |
| 54 | 36 | 9·463448 | 693 | 0·536552 | 9·482621 | 757 | 0·517379 | 0·019173 | 64 | 9·980827 | 24 | 6 |
| 55 | 40 | 9·463864 | 692 | 0·536136 | 9·483075 | 756 | 0·516925 | 0·019211 | 64 | 9·980789 | 20 | 5 |
| 56 | 44 | 9·464279 | 691 | 0·535721 | 9·483529 | 755 | 0·516471 | 0·019250 | 64 | 9·980750 | 16 | 4 |
| 57 | 48 | 9·464694 | 690 | 0·535306 | 9·483982 | 755 | 0·516018 | 0·019288 | 64 | 9·980712 | 12 | 3 |
| 58 | 52 | 9·465108 | 690 | 0·534892 | 9·484435 | 754 | 0·515565 | 0·019327 | 64 | 9·980673 | 8 | 2 |
| 59 | 56 | 9·465522 | 689 | 0·534478 | 9·484887 | 753 | 0·515113 | 0·019365 | 64 | 9·980635 | 4 | 1 |
| 60 | **8** | 9·465935 | | 0·534065 | 9·485339 | | 0·514661 | 0·019404 | | 9·980596 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

106° 73° = 4h 52m 73°

## LOG. SINES, COSINES, &c.

17° — 17° = 1h 8m — 162°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·465935 | 688 | 0·534065 | 9·485339 | 753 | 0·514661 | 0·019404 | 64 | 9·980596 | **52** | 60 |
| 1 | 4 | 9·466348 | 688 | 0·533652 | 9·485791 | 752 | 0·514209 | 0·019442 | 64 | 9 980558 | 56 | 59 |
| 2 | 8 | 9·466761 | 687 | 0·533239 | 9·486242 | 751 | 0·513758 | 0·019481 | 65 | 9·980519 | 52 | 58 |
| 3 | 12 | 9·467173 | 686 | 0·532827 | 9·486693 | 751 | 0·513307 | 0·019520 | 65 | 9 980480 | 48 | 57 |
| 4 | 16 | 9·467585 | 685 | 0·532415 | 9·487143 | 750 | 0·512857 | 0·019558 | 65 | 9·980442 | 44 | 56 |
| 5 | 20 | 9·467996 | 685 | 0·532004 | 9·487593 | 749 | 0·512407 | 0·019597 | 65 | 9·980403 | 40 | 55 |
| 6 | 24 | 9·468407 | 684 | 0·531593 | 9·488043 | 749 | 0·511957 | 0·019636 | 65 | 9·980364 | 36 | 54 |
| 7 | 28 | 9·468817 | 683 | 0·531183 | 9·488492 | 748 | 0·511508 | 0·019675 | 65 | 9·980325 | 32 | 53 |
| 8 | 32 | 9·469227 | 683 | 0·530773 | 9·488941 | 747 | 0·511059 | 0·019714 | 65 | 9·980286 | 28 | 52 |
| 9 | 36 | 9·469637 | 682 | 0·530363 | 9·489390 | 747 | 0·510610 | 0·019753 | 65 | 9·980247 | 24 | 51 |
| 10 | 40 | 9·470046 | 681 | 0·529954 | 9·489838 | 746 | 0·510162 | 0·019792 | 65 | 9·980208 | 20 | 50 |
| 11 | 44 | 9·470455 | 680 | 0·529545 | 9·490286 | 746 | 0·509714 | 0·019831 | 65 | 9·980169 | 16 | 49 |
| 12 | 48 | 9·470863 | 680 | 0·529137 | 9·490733 | 745 | 0·509267 | 0·019870 | 65 | 9 980130 | 12 | 48 |
| 13 | 52 | 9·471271 | 679 | 0·528729 | 9·491180 | 744 | 0·508820 | 0·019909 | 65 | 9·980091 | 8 | 47 |
| 14 | 56 | 9·471679 | 678 | 0·528321 | 9·491627 | 744 | 0·508373 | 0·019948 | 65 | 9·980052 | 4 | 46 |
| 15 | **9** | 9·472086 | 678 | 0·527914 | 9·492073 | 743 | 0·507927 | 0·019988 | 65 | 9·980012 | **51** | 45 |
| 16 | 4 | 9·472492 | 677 | 0·527508 | 9·492519 | 743 | 0·507481 | 0·020027 | 65 | 9·979973 | 56 | 44 |
| 17 | 8 | 9·472898 | 676 | 0·527102 | 9·492965 | 742 | 0·507035 | 0·020066 | 66 | 9·979934 | 52 | 43 |
| 18 | 12 | 9·473304 | 676 | 0·526696 | 9·493410 | 741 | 0·506590 | 0·020105 | 66 | 9·979895 | 48 | 42 |
| 19 | 16 | 9·473710 | 675 | 0·526290 | 9·493854 | 740 | 0·506146 | 0·020145 | 66 | 9 979855 | 44 | 41 |
| 20 | 20 | 9·474115 | 674 | 0·525885 | 9·494299 | 740 | 0·505701 | 0·020184 | 66 | 9·979816 | 40 | 40 |
| 21 | 24 | 9·474519 | 674 | 0·525481 | 9·494743 | 740 | 0·505257 | 0·020224 | 66 | 9·979776 | 36 | 39 |
| 22 | 28 | 9·474923 | 673 | 0·525077 | 9·495186 | 739 | 0·504814 | 0·020263 | 66 | 9·979737 | 32 | 38 |
| 23 | 32 | 9·475327 | 672 | 0·524673 | 9·495630 | 738 | 0·504370 | 0·020303 | 66 | 9·979697 | 28 | 37 |
| 24 | 36 | 9·475730 | 672 | 0·524270 | 9·496073 | 737 | 0·503927 | 0·020342 | 66 | 9·979658 | 24 | 36 |
| 25 | 40 | 9·476133 | 671 | 0·523867 | 9·496515 | 737 | 0·503485 | 0·020382 | 66 | 9·979618 | 20 | 35 |
| 26 | 44 | 9·476536 | 670 | 0·523464 | 9·496957 | 736 | 0·503043 | 0·020421 | 66 | 9·979579 | 16 | 34 |
| 27 | 48 | 9·476938 | 669 | 0·523062 | 9·497399 | 736 | 0·502601 | 0·020461 | 66 | 9·979539 | 12 | 33 |
| 28 | 52 | 9·477340 | 669 | 0·522660 | 9·497841 | 735 | 0·502159 | 0·020501 | 66 | 9·979499 | 8 | 32 |
| 29 | 56 | 9·477741 | 668 | 0·522259 | 9·498282 | 734 | 0·501718 | 0·020541 | 66 | 9·979459 | 4 | 31 |
| 30 | **10** | 9·478142 | 667 | 0·521858 | 9·498722 | 734 | 0·501278 | 0·020580 | 66 | 9·979420 | **50** | 30 |
| 31 | 4 | 9·478542 | 667 | 0·521458 | 9·499163 | 733 | 0·500837 | 0·020620 | 66 | 9·979380 | 56 | 29 |
| 32 | 8 | 9·478942 | 666 | 0·521058 | 9·499603 | 733 | 0·500397 | 0·020660 | 66 | 9·979340 | 52 | 28 |
| 33 | 12 | 9·479342 | 665 | 0·520658 | 9·500042 | 732 | 0·499958 | 0·020700 | 67 | 9·979300 | 48 | 27 |
| 34 | 16 | 9·479741 | 665 | 0·520259 | 9·500481 | 731 | 0·499519 | 0·020740 | 67 | 9·979260 | 44 | 26 |
| 35 | 20 | 9·480140 | 664 | 0·519860 | 9·500920 | 731 | 0·499080 | 0·020780 | 67 | 9·979220 | 40 | 25 |
| 36 | 24 | 9·480539 | 663 | 0·519461 | 9·501359 | 730 | 0·498641 | 0·020820 | 67 | 9·979180 | 36 | 24 |
| 37 | 28 | 9·480937 | 663 | 0·519063 | 9·501797 | 730 | 0·498203 | 0·020860 | 67 | 9·979140 | 32 | 23 |
| 38 | 32 | 9·481334 | 662 | 0·518666 | 9·502235 | 729 | 0·497765 | 0·020900 | 67 | 9·979100 | 28 | 22 |
| 39 | 36 | 9·481731 | 661 | 0·518269 | 9·502672 | 728 | 0·497328 | 0·020941 | 67 | 9·979059 | 24 | 21 |
| 40 | 40 | 9·482128 | 661 | 0·517872 | 9·503109 | 728 | 0·496891 | 0·020981 | 67 | 9·979019 | 20 | 20 |
| 41 | 44 | 9·482525 | 660 | 0·517475 | 9·503546 | 727 | 0·496454 | 0·021021 | 67 | 9·978979 | 16 | 19 |
| 42 | 48 | 9·482921 | 659 | 0·517079 | 9·503982 | 727 | 0·496018 | 0·021061 | 67 | 9·978939 | 12 | 18 |
| 43 | 52 | 9·483316 | 659 | 0·516684 | 9·504418 | 726 | 0·495582 | 0·021102 | 67 | 9·978898 | 8 | 17 |
| 44 | 56 | 9·483712 | 658 | 0·516288 | 9·504854 | 725 | 0·495146 | 0·021142 | 67 | 9·978858 | 4 | 16 |
| 45 | **11** | 9·484107 | 657 | 0·515893 | 9·505289 | 725 | 0·494711 | 0·021183 | 67 | 9·978817 | **49** | 15 |
| 46 | 4 | 9·484501 | 657 | 0·515499 | 9·505724 | 724 | 0·494276 | 0·021223 | 67 | 9·978777 | 56 | 14 |
| 47 | 8 | 9·484895 | 656 | 0·515105 | 9·506159 | 724 | 0·493841 | 0·021263 | 67 | 9·978737 | 52 | 13 |
| 48 | 12 | 9·485289 | 655 | 0·514711 | 9·506593 | 723 | 0·493407 | 0·021304 | 68 | 9·978696 | 48 | 12 |
| 49 | 16 | 9·485682 | 655 | 0·514318 | 9·507027 | 722 | 0·492973 | 0·021345 | 68 | 9·978655 | 44 | 11 |
| 50 | 20 | 9·486075 | 654 | 0·513925 | 9·507460 | 722 | 0·492540 | 0·021385 | 68 | 9·978615 | 40 | 10 |
| 51 | 24 | 9·486467 | 653 | 0·513533 | 9·507893 | 721 | 0·492107 | 0·021426 | 68 | 9·978574 | 36 | 9 |
| 52 | 28 | 9·486860 | 653 | 0·513140 | 9·508326 | 721 | 0·491674 | 0·021467 | 68 | 9·978533 | 32 | 8 |
| 53 | 32 | 9·487251 | 652 | 0·512749 | 9·508759 | 720 | 0·491241 | 0·021507 | 68 | 9·978493 | 28 | 7 |
| 54 | 36 | 9·487643 | 651 | 0·512357 | 9·509191 | 719 | 0·490809 | 0·021548 | 68 | 9·978452 | 24 | 6 |
| 55 | 40 | 9·488034 | 651 | 0·511966 | 9·509622 | 719 | 0·490378 | 0·021589 | 68 | 9·978411 | 20 | 5 |
| 56 | 44 | 9·488424 | 650 | 0·511576 | 9·510054 | 718 | 0·489946 | 0·021630 | 68 | 9·978370 | 16 | 4 |
| 57 | 48 | 9·488814 | 650 | 0·511186 | 9·510485 | 718 | 0·489515 | 0·021671 | 68 | 9·978329 | 12 | 3 |
| 58 | 52 | 9·489204 | 649 | 0·510796 | 9·510916 | 717 | 0·489084 | 0·021712 | 68 | 9·978288 | 8 | 2 |
| 59 | 56 | 9·489593 | 648 | 0·510407 | 9·511346 | 716 | 0·488654 | 0·021753 | 68 | 9·978247 | 4 | 1 |
| 60 | **12** | 9·489982 | | 0·510018 | 9·511776 | | 0·488224 | 0·021794 | | 9·978206 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

107° — 72° = 4h 48m — 72°

## LOG. SINES, COSINES, &c.

18° 18°=1h 12m 161°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·489982 | 648 | 0·510018 | 9 511776 | 716 | 0·488224 | 0·021794 | 68 | 9·978206 | **48** | 60 |
| 1 | 4 | 9·490371 | 648 | 0·509629 | 9 512206 | 716 | 0·487794 | 0·021835 | 68 | 9 978165 | 56 | 59 |
| 2 | 8 | 9·490759 | 647 | 0·509241 | 9·512635 | 715 | 0·487365 | 0·021876 | 68 | 9 978124 | 52 | 58 |
| 3 | 12 | 9·491147 | 646 | 0·508853 | 9 513064 | 714 | 0·486936 | 0·021917 | 69 | 9 978083 | 48 | 57 |
| 4 | 16 | 9·491535 | 646 | 0·508465 | 9 513493 | 714 | 0·486507 | 0·021958 | 69 | 9 978042 | 44 | 56 |
| 5 | 20 | 9·491922 | 645 | 0·508078 | 9 513921 | 713 | 0·486079 | 0·021999 | 69 | 9 978001 | 40 | 55 |
| 6 | 24 | 9·492308 | 644 | 0·507692 | 9 514349 | 713 | 0·485651 | 0·022041 | 69 | 9 977959 | 36 | 54 |
| 7 | 28 | 9·492695 | 644 | 0·507305 | 9 514777 | 712 | 0·485223 | 0·022082 | 69 | 9 977918 | 32 | 53 |
| 8 | 32 | 9·493081 | 643 | 0·506919 | 9 515204 | 712 | 0·484796 | 0·022123 | 69 | 9 977877 | 28 | 52 |
| 9 | 36 | 9·493466 | 642 | 0·506534 | 9 515631 | 711 | 0·484369 | 0·022165 | 69 | 9 977835 | 24 | 51 |
| 10 | 40 | 9·493851 | 642 | 0·506149 | 9·516057 | 710 | 0·483943 | 0·022206 | 69 | 9 977794 | 20 | 50 |
| 11 | 44 | 9·494236 | 641 | 0·505764 | 9·516484 | 710 | 0·483516 | 0·022248 | 69 | 9·977752 | 16 | 49 |
| 12 | 48 | 9·494621 | 641 | 0 505379 | 9 516910 | 709 | 0·483090 | 0·022289 | 69 | 9 977711 | 12 | 48 |
| 13 | 52 | 9·495005 | 640 | 0·504995 | 9 517335 | 709 | 0·482665 | 0·022331 | 69 | 9 977669 | 8 | 47 |
| 14 | 56 | 9·495388 | 639 | 0·504612 | 9·517761 | 708 | 0·482239 | 0·022372 | 69 | 9 977628 | 4 | 46 |
| 15 | **13** | 9·495772 | 639 | 0·504228 | 9·518186 | 708 | 0·481814 | 0·022414 | 69 | 9·977586 | **47** | 45 |
| 16 | 4 | 9·496154 | 638 | 0·503846 | 9·518610 | 707 | 0·481390 | 0·022456 | 69 | 9 977544 | 56 | 44 |
| 17 | 8 | 9·496537 | 637 | 0·503463 | 9·519034 | 706 | 0·480966 | 0·022497 | 70 | 9 977503 | 52 | 43 |
| 18 | 12 | 9·496919 | 637 | 0·503081 | 9 519458 | 706 | 0·480542 | 0·022539 | 70 | 9 977461 | 48 | 42 |
| 19 | 16 | 9·497301 | 636 | 0·502699 | 9·519882 | 705 | 0·480118 | 0·022581 | 70 | 9 977419 | 44 | 41 |
| 20 | 20 | 9·497682 | 636 | 0·502318 | 9 520305 | 705 | 0·479695 | 0·022623 | 70 | 9 977377 | 40 | 40 |
| 21 | 24 | 9 498064 | 635 | 0·501936 | 9·520728 | 704 | 0·479272 | 0·022665 | 70 | 9·977335 | 36 | 39 |
| 22 | 28 | 9·498444 | 634 | 0·501556 | 9·521151 | 703 | 0·478849 | 0·022707 | 70 | 9 977293 | 32 | 38 |
| 23 | 32 | 9 498825 | 634 | 0·501175 | 9·521573 | 703 | 0·478427 | 0·022749 | 70 | 9 977251 | 28 | 37 |
| 24 | 36 | 9·499204 | 633 | 0·500796 | 9·521995 | 703 | 0·478005 | 0·022791 | 70 | 9·977209 | 24 | 36 |
| 25 | 40 | 9·499584 | 632 | 0·500416 | 9·522417 | 702 | 0·477583 | 0·022833 | 70 | 9 977167 | 20 | 35 |
| 26 | 44 | 9·499963 | 632 | 0·500037 | 9·522838 | 702 | 0·477162 | 0·022875 | 70 | 9·977125 | 16 | 34 |
| 27 | 48 | 9 500342 | 631 | 0·499658 | 9·523259 | 701 | 0·476741 | 0·022917 | 70 | 9·977083 | 12 | 33 |
| 28 | 52 | 9·500721 | 631 | 0·499279 | 9·523680 | 701 | 0·476320 | 0·022959 | 70 | 9 977041 | 8 | 32 |
| 29 | 56 | 9·501099 | 630 | 0·498901 | 9·524100 | 700 | 0·475900 | 0·023001 | 70 | 9·976999 | 4 | 31 |
| 30 | **14** | 9·501476 | 629 | 0·498524 | 9·524520 | 699 | 0·475480 | 0·023043 | 70 | 9 976957 | **46** | 30 |
| 31 | 4 | 9·501854 | 629 | 0·498146 | 9·524940 | 699 | 0·475060 | 0·023086 | 70 | 9·976914 | 56 | 29 |
| 32 | 8 | 9·502231 | 628 | 0·497769 | 9·525359 | 698 | 0·474641 | 0·023128 | 71 | 9·976872 | 52 | 28 |
| 33 | 12 | 9·502607 | 628 | 0·497393 | 9·525778 | 698 | 0·474222 | 0·023170 | 71 | 9·976830 | 48 | 27 |
| 34 | 16 | 9·502984 | 627 | 0·497016 | 9·526197 | 697 | 0·473803 | 0·023213 | 71 | 9·976787 | 44 | 26 |
| 35 | 20 | 9·503360 | 626 | 0·496640 | 9·526615 | 697 | 0·473385 | 0·023255 | 71 | 9·976745 | 40 | 25 |
| 36 | 24 | 9·503735 | 626 | 0·496265 | 9·527033 | 696 | 0·472967 | 0·023298 | 71 | 9·976702 | 36 | 24 |
| 37 | 28 | 9·504110 | 625 | 0·495890 | 9·527451 | 696 | 0·472549 | 0·023340 | 71 | 9·976660 | 32 | 23 |
| 38 | 32 | 9·504485 | 625 | 0·495515 | 9·527868 | 695 | 0·472132 | 0·023383 | 71 | 9·976617 | 28 | 22 |
| 39 | 36 | 9·504860 | 624 | 0·495140 | 9·528285 | 695 | 0·471715 | 0·023426 | 71 | 9·976574 | 24 | 21 |
| 40 | 40 | 9·505234 | 623 | 0·494766 | 9·528702 | 694 | 0·471298 | 0·023468 | 71 | 9·976532 | 20 | 20 |
| 41 | 44 | 9·505608 | 623 | 0·494392 | 9·529119 | 693 | 0·470881 | 0·023511 | 71 | 9·976489 | 16 | 19 |
| 42 | 48 | 9·505981 | 622 | 0·494019 | 9·529535 | 693 | 0·470465 | 0·023554 | 71 | 9·976446 | 12 | 18 |
| 43 | 52 | 9·506354 | 622 | 0·493646 | 9·529951 | 693 | 0·470049 | 0·023596 | 71 | 9·976404 | 8 | 17 |
| 44 | 56 | 9·506727 | 621 | 0·493273 | 9·530366 | 692 | 0·469634 | 0·023639 | 71 | 9·976361 | 4 | 16 |
| 45 | **15** | 9·507099 | 620 | 0·492901 | 9·530781 | 691 | 0·469219 | 0·023682 | 71 | 9·976318 | **45** | 15 |
| 46 | 4 | 9·507471 | 620 | 0·492529 | 9·531196 | 691 | 0·468804 | 0·023725 | 71 | 9·976275 | 56 | 14 |
| 47 | 8 | 9·507843 | 619 | 0·492157 | 9·531611 | 690 | 0·468389 | 0·023768 | 72 | 9·976232 | 52 | 13 |
| 48 | 12 | 9·508214 | 619 | 0·491786 | 9·532025 | 690 | 0·467975 | 0·023811 | 72 | 9·976189 | 48 | 12 |
| 49 | 16 | 9·508585 | 618 | 0·491415 | 9·532439 | 689 | 0·467561 | 0·023854 | 72 | 9·976146 | 44 | 11 |
| 50 | 20 | 9·508956 | 618 | 0·491044 | 9·532853 | 689 | 0·467147 | 0·023897 | 72 | 9·976103 | 40 | 10 |
| 51 | 24 | 9·509326 | 617 | 0·490674 | 9·533266 | 688 | 0·466734 | 0·023940 | 72 | 9 976060 | 36 | 9 |
| 52 | 28 | 9·509696 | 616 | 0·490304 | 9·533679 | 688 | 0·466321 | 0·023983 | 72 | 9·976017 | 32 | 8 |
| 53 | 32 | 9·510065 | 616 | 0·489935 | 9·534092 | 687 | 0·465908 | 0·024026 | 72 | 9·975974 | 28 | 7 |
| 54 | 36 | 9·510434 | 615 | 0·489566 | 9·534504 | 687 | 0·465496 | 0·024070 | 72 | 9·975930 | 24 | 6 |
| 55 | 40 | 9·510803 | 615 | 0·489197 | 9·534916 | 686 | 0·465084 | 0·024113 | 72 | 9·975887 | 20 | 5 |
| 56 | 44 | 9·511172 | 614 | 0·488828 | 9·535328 | 686 | 0·464672 | 0·024156 | 72 | 9·975844 | 16 | 4 |
| 57 | 48 | 9·511540 | 613 | 0·488460 | 9·535739 | 685 | 0·464261 | 0·024200 | 72 | 9·975800 | 12 | 3 |
| 58 | 52 | 9·511907 | 613 | 0·488093 | 9·536150 | 685 | 0·463850 | 0·024243 | 72 | 9·975757 | 8 | 2 |
| 59 | 56 | 9·512275 | 612 | 0·487725 | 9·536561 | 684 | 0·463439 | 0·024286 | 72 | 9·975714 | 4 | 1 |
| 60 | **16** | 9·512642 | | 0·487358 | 9·536972 | | 0·463028 | 0·024330 | | 9·975670 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

108° 71°=4h 44m 71°

## LOG. SINES, COSINES, &c.

19° 19°=1h 16m 160°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·512642 | 612 | 0·487358 | 9 536972 | 684 | 0·463028 | 0·024330 | 73 | 9·975670 | 44 | 60 |
| 1 | 4 | 9 513009 | 611 | 0·486991 | 9 537382 | 683 | 0·462618 | 0 024373 | 73 | 9 975627 | 56 | 59 |
| 2 | 8 | 9 513375 | 611 | 0 486625 | 9 537792 | 683 | 0·462208 | 0·024417 | 73 | 9 975583 | 52 | 58 |
| 3 | 12 | 9 513741 | 610 | 0 486259 | 9 538202 | 682 | 0·461798 | 0 024461 | 73 | 9 97553g | 48 | 57 |
| 4 | 16 | 9·514107 | 609 | 0·485893 | 9 538611 | 682 | 0·461389 | 0 024504 | 73 | 9 975496 | 44 | 56 |
| 5 | 20 | 9 514472 | 609 | 0·485528 | 9 539020 | 681 | 0·460980 | 0·024548 | 73 | 9 975452 | 40 | 55 |
| 6 | 24 | 9 514837 | 608 | 0·485163 | 9 539429 | 681 | 0 460571 | 0·024592 | 73 | 9·975408 | 36 | 54 |
| 7 | 28 | 9 515202 | 608 | 0·484798 | 9 539837 | 680 | 0 460163 | 0 024635 | 73 | 9 975365 | 32 | 53 |
| 8 | 32 | 9 515566 | 607 | 0 484434 | 9 540245 | 680 | 0·459755 | 0 024679 | 73 | 9 975321 | 28 | 52 |
| 9 | 36 | 9 515930 | 607 | 0·484070 | 9 540653 | 679 | 0 459347 | 0 024723 | 73 | 9 975277 | 24 | 51 |
| 10 | 40 | 9 516294 | 606 | 0·483706 | 9 541061 | 679 | 0·458939 | 0·024767 | 73 | 9 975233 | 20 | 50 |
| 11 | 44 | 9 516657 | 605 | 0 483343 | 9 541468 | 678 | 0 458532 | 0 024811 | 73 | 9·975189 | 16 | 49 |
| 12 | 48 | 9 517020 | 605 | 0 482980 | 9 541875 | 678 | 0·458125 | 0·024855 | 73 | 9 975145 | 12 | 48 |
| 13 | 52 | 9·517382 | 604 | 0·482618 | 9 542281 | 677 | 0·457719 | 0·024899 | 73 | 9 975101 | 8 | 47 |
| 14 | 56 | 9 517745 | 604 | 0 482255 | 9 542688 | 677 | 0·457312 | 0·024943 | 73 | 9 975057 | 4 | 46 |
| 15 | 17 | 9 518107 | 603 | 0 481893 | 9 543094 | 676 | 0·456906 | 0·024987 | 73 | 9 975013 | 43 | 45 |
| 16 | 4 | 9 518468 | 603 | 0·481532 | 9 543499 | 676 | 0 456501 | 0·025031 | 74 | 9·974969 | 56 | 44 |
| 17 | 8 | 9 518829 | 602 | 0 481171 | 9 543905 | 675 | 0·456095 | 0·025075 | 74 | 9 974925 | 52 | 43 |
| 18 | 12 | 9 519190 | 601 | 0 480810 | 9 544310 | 675 | 0 455690 | 0·025120 | 74 | 9 974880 | 48 | 42 |
| 19 | 16 | 9 519551 | 601 | 0 480449 | 9 544715 | 674 | 0 455285 | 0·025164 | 74 | 9 974836 | 44 | 41 |
| 20 | 20 | 9·519911 | 600 | 0 480089 | 9 545119 | 674 | 0·454881 | 0 025208 | 74 | 9 974792 | 40 | 40 |
| 21 | 24 | 9 520271 | 600 | 0·479729 | 9 545524 | 673 | 0 454476 | 0·025252 | 74 | 9 974748 | 36 | 39 |
| 22 | 28 | 9 520631 | 599 | 0·479369 | 9 545928 | 673 | 0 454072 | 0 025297 | 74 | 9 974703 | 32 | 38 |
| 23 | 32 | 9 520990 | 599 | 0 479010 | 9 546331 | 672 | 0 453669 | 0·025341 | 74 | 9 974659 | 28 | 37 |
| 24 | 36 | 9 521349 | 598 | 0 478651 | 9 546735 | 672 | 0 453265 | 0·025386 | 74 | 9 974614 | 24 | 36 |
| 25 | 40 | 9 521707 | 598 | 0·478293 | 9 547138 | 671 | 0·452862 | 0·025430 | 74 | 9 974570 | 20 | 35 |
| 26 | 44 | 9 522066 | 597 | 0 477934 | 9 547540 | 671 | 0 452460 | 0·025475 | 74 | 9·974525 | 16 | 34 |
| 27 | 48 | 9 522424 | 596 | 0 477576 | 9 547943 | 670 | 0 452057 | 0·025519 | 74 | 9 974481 | 12 | 33 |
| 28 | 52 | 9 522781 | 596 | 0 477219 | 9 548345 | 670 | 0 451655 | 0·025564 | 74 | 9 974436 | 8 | 32 |
| 29 | 56 | 9 523138 | 595 | 0·476862 | 9 548747 | 669 | 0·451253 | 0·025609 | 74 | 9 974391 | 4 | 31 |
| 30 | 18 | 9 523495 | 595 | 0·476505 | 9·549149 | 669 | 0 450851 | 0 025653 | 75 | 9 974347 | 42 | 30 |
| 31 | 4 | 9 523852 | 594 | 0·476148 | 9 549550 | 668 | 0 450450 | 0 025698 | 75 | 9 974302 | 56 | 29 |
| 32 | 8 | 9 524208 | 594 | 0·475792 | 9 549951 | 668 | 0·450049 | 0 025743 | 75 | 9 974257 | 52 | 28 |
| 33 | 12 | 9 524564 | 593 | 0·475436 | 9 550352 | 667 | 0 449648 | 0·025788 | 75 | 9 974212 | 48 | 27 |
| 34 | 16 | 9 524920 | 593 | 0·475080 | 9 550752 | 667 | 0·449248 | 0·025833 | 75 | 9 974167 | 44 | 26 |
| 35 | 20 | 9·525275 | 592 | 0·474725 | 9 551153 | 666 | 0·448847 | 0·025878 | 75 | 9 974122 | 40 | 25 |
| 36 | 24 | 9 525630 | 591 | 0·474370 | 9 551552 | 666 | 0·448448 | 0·025923 | 75 | 9 974077 | 36 | 24 |
| 37 | 28 | 9 525984 | 591 | 0·474016 | 9 551952 | 665 | 0·448048 | 0·025968 | 75 | 9 974032 | 32 | 23 |
| 38 | 32 | 9 526339 | 590 | 0 473661 | 9 552351 | 665 | 0 447649 | 0·026013 | 75 | 9 973987 | 28 | 22 |
| 39 | 36 | 9 526693 | 590 | 0·473307 | 9·552750 | 665 | 0 447250 | 0·026058 | 75 | 9 973942 | 24 | 21 |
| 40 | 40 | 9 527046 | 589 | 0·472954 | 9 553149 | 664 | 0 446851 | 0·026103 | 75 | 9·973897 | 20 | 20 |
| 41 | 44 | 9 527400 | 589 | 0·472600 | 9 553548 | 664 | 0 446452 | 0·026148 | 75 | 9 973852 | 16 | 19 |
| 42 | 48 | 9·527753 | 588 | 0·472247 | 9 553946 | 663 | 0 446054 | 0·026193 | 75 | 9 973807 | 12 | 18 |
| 43 | 52 | 9·528105 | 588 | 0·471895 | 9 554344 | 663 | 0 445656 | 0·026239 | 75 | 9 973761 | 8 | 17 |
| 44 | 56 | 9 528458 | 587 | 0·471542 | 9·554741 | 662 | 0 445259 | 0·026284 | 75 | 9 973716 | 4 | 16 |
| 45 | 19 | 9 528810 | 587 | 0·471190 | 9 555139 | 662 | 0·444861 | 0·026329 | 76 | 9·973671 | 41 | 15 |
| 46 | 4 | 9·529161 | 586 | 0·470839 | 9 555536 | 661 | 0 444464 | 0·026375 | 76 | 9 973625 | 56 | 14 |
| 47 | 8 | 9 529513 | 586 | 0·470487 | 9 555933 | 661 | 0 444067 | 0·026420 | 76 | 9 973580 | 52 | 13 |
| 48 | 12 | 9 529864 | 585 | 0 470136 | 9 556329 | 660 | 0 443671 | 0·026465 | 76 | 9 973535 | 48 | 12 |
| 49 | 16 | 9 530215 | 585 | 0·469785 | 9 556725 | 660 | 0 443275 | 0·026511 | 76 | 9 973489 | 44 | 11 |
| 50 | 20 | 9·530565 | 584 | 0·469435 | 9 557121 | 659 | 0·442879 | 0·026556 | 76 | 9 973444 | 40 | 10 |
| 51 | 24 | 9 530915 | 584 | 0·469085 | 9·557517 | 659 | 0·442483 | 0·026602 | 76 | 9 973398 | 36 | 9 |
| 52 | 28 | 9 531265 | 583 | 0·468735 | 9 557913 | 659 | 0 442087 | 0·026648 | 76 | 9 973352 | 32 | 8 |
| 53 | 32 | 9 531614 | 582 | 0·468386 | 9·558308 | 658 | 0·441692 | 0·026693 | 76 | 9·973307 | 28 | 7 |
| 54 | 36 | 9 531963 | 582 | 0·468037 | 9 558703 | 658 | 0·441297 | 0·026739 | 76 | 9 973261 | 24 | 6 |
| 55 | 40 | 9 532312 | 581 | 0·467688 | 9 559097 | 657 | 0·440903 | 0·026785 | 76 | 9·973215 | 20 | 5 |
| 56 | 44 | 9 532661 | 581 | 0·467339 | 9·559491 | 657 | 0·440509 | 0·026831 | 76 | 9·973169 | 16 | 4 |
| 57 | 48 | 9·533009 | 580 | 0·466991 | 9 559885 | 656 | 0·440115 | 0·026876 | 76 | 9·973124 | 12 | 3 |
| 58 | 52 | 9·533357 | 580 | 0·466643 | 9 560279 | 656 | 0·439721 | 0·026922 | 76 | 9·973078 | 8 | 2 |
| 59 | 56 | 9·533704 | 579 | 0·466296 | 9·560673 | 655 | 0·439327 | 0·026968 | 77 | 9·973032 | 4 | 1 |
| 60 | 20 | 9·534052 | | 0·465948 | 9·561066 | | 0·438934 | 0·027014 | | 9·972986 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. S. | ′ |

109° 70°=4h 40m 70°

## LOG. SINES, COSINES, &c.

20° 20°=1h 20m 159°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·534052 | 578 | 0·465948 | 9·561066 | 655 | 0·438934 | 0·027014 | 77 | 9·972986 | **40** | 60 |
| 1 | 4 | 9·534399 | 577 | 0·465601 | 9·561459 | 654 | 0·438541 | 0·027060 | 77 | 9·972940 | 56 | 59 |
| 2 | 8 | 9·534745 | 577 | 0·465255 | 9·561851 | 654 | 0·438149 | 0·027106 | 77 | 9·972894 | 52 | 58 |
| 3 | 12 | 9·535092 | 577 | 0·464908 | 9·562244 | 653 | 0·437756 | 0·027152 | 77 | 9·972848 | 48 | 57 |
| 4 | 16 | 9·535438 | 576 | 0·464562 | 9·562636 | 653 | 0·437364 | 0·027198 | 77 | 9·972802 | 44 | 56 |
| 5 | 20 | 9·535783 | 576 | 0·464217 | 9·563028 | 653 | 0·436972 | 0·027245 | 77 | 9·972755 | 40 | 55 |
| 6 | 24 | 9·536129 | 575 | 0·463871 | 9·563419 | 652 | 0·436581 | 0·027291 | 77 | 9·972709 | 36 | 54 |
| 7 | 28 | 9·536474 | 574 | 0·463526 | 9·563811 | 652 | 0·436189 | 0·027337 | 77 | 9·972663 | 32 | 53 |
| 8 | 32 | 9·536818 | 574 | 0·463182 | 9·564202 | 651 | 0·435798 | 0·027383 | 77 | 9·972617 | 28 | 52 |
| 9 | 36 | 9·537163 | 573 | 0·462837 | 9·564593 | 651 | 0·435407 | 0·027430 | 77 | 9·972570 | 24 | 51 |
| 10 | 40 | 9·537507 | 573 | 0·462493 | 9·564983 | 650 | 0·435017 | 0·027476 | 77 | 9·972524 | 20 | 50 |
| 11 | 44 | 9·537851 | 572 | 0·462149 | 9·565373 | 650 | 0·434627 | 0·027522 | 77 | 9·972478 | 16 | 49 |
| 12 | 48 | 9·538194 | 572 | 0·461806 | 9·565763 | 649 | 0·434237 | 0·027569 | 78 | 9·972431 | 12 | 48 |
| 13 | 52 | 9·538538 | 571 | 0·461462 | 9·566153 | 649 | 0·433847 | 0·027615 | 78 | 9·972385 | 8 | 47 |
| 14 | 56 | 9·538880 | 571 | 0·461120 | 9·566542 | 649 | 0·433458 | 0·027662 | 78 | 9·972338 | 4 | 46 |
| 15 | **21** | 9·539223 | 570 | 0·460777 | 9·566932 | 648 | 0·433068 | 0·027709 | 78 | 9·972291 | **39** | 45 |
| 16 | 4 | 9·539565 | 570 | 0·460435 | 9·567320 | 648 | 0·432680 | 0·027755 | 78 | 9·972245 | 56 | 44 |
| 17 | 8 | 9·539907 | 569 | 0·460093 | 9·567709 | 647 | 0·432291 | 0·027802 | 78 | 9·972198 | 52 | 43 |
| 18 | 12 | 9·540249 | 569 | 0·459751 | 9·568098 | 647 | 0·431902 | 0·027849 | 78 | 9·972151 | 48 | 42 |
| 19 | 16 | 9·540590 | 568 | 0·459410 | 9·568486 | 646 | 0·431514 | 0·027895 | 78 | 9·972105 | 44 | 41 |
| 20 | 20 | 9·540931 | 568 | 0·459069 | 9·568873 | 646 | 0·431127 | 0·027942 | 78 | 9·972058 | 40 | 40 |
| 21 | 24 | 9·541272 | 567 | 0·458728 | 9·569261 | 645 | 0·430739 | 0·027989 | 78 | 9·972011 | 36 | 39 |
| 22 | 28 | 9·541613 | 567 | 0·458387 | 9·569648 | 645 | 0·430352 | 0·028036 | 78 | 9·971964 | 32 | 38 |
| 23 | 32 | 9·541953 | 566 | 0·458047 | 9·570035 | 645 | 0·429965 | 0·028083 | 78 | 9·971917 | 28 | 37 |
| 24 | 36 | 9·542293 | 566 | 0·457707 | 9·570422 | 644 | 0·429578 | 0·028130 | 78 | 9·971870 | 24 | 36 |
| 25 | 40 | 9·542632 | 565 | 0·457368 | 9·570809 | 644 | 0·429191 | 0·028177 | 78 | 9·971823 | 20 | 35 |
| 26 | 44 | 9·542971 | 565 | 0·457029 | 9·571195 | 643 | 0·428805 | 0·028224 | 78 | 9·971776 | 16 | 34 |
| 27 | 48 | 9·543310 | 564 | 0·456690 | 9·571581 | 643 | 0·428419 | 0·028271 | 79 | 9·971729 | 12 | 33 |
| 28 | 52 | 9·543649 | 564 | 0·456351 | 9·571967 | 642 | 0·428033 | 0·028318 | 79 | 9·971682 | 8 | 32 |
| 29 | 56 | 9·543987 | 563 | 0·456013 | 9·572352 | 642 | 0·427648 | 0·028365 | 79 | 9·971635 | 4 | 31 |
| 30 | **22** | 9·544325 | 563 | 0·455675 | 9·572738 | 642 | 0·427262 | 0·028412 | 79 | 9·971588 | **38** | 30 |
| 31 | 4 | 9·544663 | 562 | 0·455337 | 9·573123 | 641 | 0·426877 | 0·028460 | 79 | 9·971540 | 56 | 29 |
| 32 | 8 | 9·545000 | 562 | 0·455000 | 9·573507 | 641 | 0·426493 | 0·028507 | 79 | 9·971493 | 52 | 28 |
| 33 | 12 | 9·545338 | 561 | 0·454662 | 9·573892 | 640 | 0·426108 | 0·028554 | 79 | 9·971446 | 48 | 27 |
| 34 | 16 | 9·545674 | 561 | 0·454326 | 9·574276 | 640 | 0·425724 | 0·028602 | 79 | 9·971398 | 44 | 26 |
| 35 | 20 | 9·546011 | 560 | 0·453989 | 9·574660 | 639 | 0·425340 | 0·028649 | 79 | 9·971351 | 40 | 25 |
| 36 | 24 | 9·546347 | 560 | 0·453653 | 9·575044 | 639 | 0·424956 | 0·028697 | 79 | 9·971303 | 36 | 24 |
| 37 | 28 | 9·546683 | 559 | 0·453317 | 9·575427 | 639 | 0·424573 | 0·028744 | 79 | 9·971256 | 32 | 23 |
| 38 | 32 | 9·547019 | 559 | 0·452981 | 9·575810 | 638 | 0·424190 | 0·028792 | 79 | 9·971208 | 28 | 22 |
| 39 | 36 | 9·547354 | 558 | 0·452646 | 9·576193 | 638 | 0·423807 | 0·028839 | 79 | 9·971161 | 24 | 21 |
| 40 | 40 | 9·547689 | 558 | 0·452311 | 9·576576 | 637 | 0·423424 | 0·028887 | 79 | 9·971113 | 20 | 20 |
| 41 | 44 | 9·548024 | 557 | 0·451976 | 9·576959 | 637 | 0·423041 | 0·028934 | 80 | 9·971066 | 16 | 19 |
| 42 | 48 | 9·548359 | 557 | 0·451641 | 9·577341 | 636 | 0·422659 | 0·028982 | 80 | 9·971018 | 12 | 18 |
| 43 | 52 | 9·548693 | 556 | 0·451307 | 9·577723 | 636 | 0·422277 | 0·029030 | 80 | 9·970970 | 8 | 17 |
| 44 | 56 | 9·549027 | 556 | 0·450973 | 9·578104 | 636 | 0·421896 | 0·029078 | 80 | 9·970922 | 4 | 16 |
| 45 | **23** | 9·549360 | 555 | 0·450640 | 9·578486 | 635 | 0·421514 | 0·029126 | 80 | 9·970874 | **37** | 15 |
| 46 | 4 | 9·549693 | 555 | 0·450307 | 9·578867 | 635 | 0·421133 | 0·029173 | 80 | 9·970827 | 56 | 14 |
| 47 | 8 | 9·550026 | 554 | 0·449974 | 9·579248 | 634 | 0·420752 | 0·029221 | 80 | 9·970779 | 52 | 13 |
| 48 | 12 | 9·550359 | 554 | 0·449641 | 9·579629 | 634 | 0·420371 | 0·029269 | 80 | 9·970731 | 48 | 12 |
| 49 | 16 | 9·550692 | 553 | 0·449308 | 9·580009 | 634 | 0·419991 | 0·029317 | 80 | 9·970683 | 44 | 11 |
| 50 | 20 | 9·551024 | 553 | 0·448976 | 9·580389 | 633 | 0·419611 | 0·029365 | 80 | 9·970635 | 40 | 10 |
| 51 | 24 | 9·551356 | 552 | 0·448644 | 9·580769 | 633 | 0·419231 | 0·029414 | 80 | 9·970586 | 36 | 9 |
| 52 | 28 | 9·551687 | 552 | 0·448313 | 9·581149 | 632 | 0·418851 | 0·029462 | 80 | 9·970538 | 32 | 8 |
| 53 | 32 | 9·552018 | 552 | 0·447982 | 9·581528 | 632 | 0·418472 | 0·029510 | 80 | 9·970490 | 28 | 7 |
| 54 | 36 | 9·552349 | 551 | 0·447651 | 9·581907 | 632 | 0·418093 | 0·029558 | 80 | 9·970442 | 24 | 6 |
| 55 | 40 | 9·552680 | 551 | 0·447320 | 9·582286 | 631 | 0·417714 | 0·029606 | 80 | 9·970394 | 20 | 5 |
| 56 | 44 | 9·553010 | 550 | 0·446990 | 9·582665 | 631 | 0·417335 | 0·029655 | 81 | 9·970345 | 16 | 4 |
| 57 | 48 | 9·553341 | 550 | 0·446659 | 9·583044 | 630 | 0·416956 | 0·029703 | 81 | 9·970297 | 12 | 3 |
| 58 | 52 | 9·553670 | 549 | 0·446330 | 9·583422 | 630 | 0·416578 | 0·029751 | 81 | 9·970249 | 8 | 2 |
| 59 | 56 | 9·554000 | 549 | 0·446000 | 9·583800 | 629 | 0·416200 | 0·029800 | 81 | 9·970200 | 4 | 1 |
| 60 | **24** | 9·554329 | | 0·445671 | 9·584177 | | 0·415823 | 0·029848 | | 9·970152 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

110° 69°=4h 36m 69°

## LOG. SINES, COSINES, &c.

21° 21°=1h 24m 158°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·554329 | 548 | 0·445671 | 9·584177 | 629 | 0·415823 | 0·029848 | 81 | 9·970152 | **36** | 60 |
| 1 | 4 | 9 554658 | 548 | 0·445342 | 9 584555 | 629 | 0·415445 | 0·029897 | 81 | 9·970103 | 56 | 59 |
| 2 | 8 | 9·554987 | 547 | 0·445013 | 9·584932 | 628 | 0·415068 | 0·029945 | 81 | 9 970055 | 52 | 58 |
| 3 | 12 | 9 555315 | 547 | 0·444685 | 9·585309 | 628 | 0·414691 | 0·029994 | 81 | 9 970006 | 48 | 57 |
| 4 | 16 | 9 555643 | 546 | 0·444357 | 9·585686 | 627 | 0·414314 | 0·030043 | 81 | 9·969957 | 44 | 56 |
| 5 | 20 | 9 555971 | 546 | 0·444029 | 9 586062 | 627 | 0·413938 | 0·030091 | 81 | 9 969909 | 40 | 55 |
| 6 | 24 | 9·556299 | 545 | 0·443701 | 9·586439 | 627 | 0·413561 | 0·030140 | 81 | 9·969860 | 36 | 54 |
| 7 | 28 | 9 556626 | 545 | 0·443374 | 9 586815 | 626 | 0·413185 | 0·030189 | 81 | 9 969811 | 32 | 53 |
| 8 | 32 | 9·556953 | 544 | 0·443047 | 9·587190 | 626 | 0·412810 | 0·030238 | 81 | 9 969762 | 28 | 52 |
| 9 | 36 | 9 557280 | 544 | 0·442720 | 9 587566 | 625 | 0·412434 | 0·030286 | 81 | 9·969714 | 24 | 51 |
| 10 | 40 | 9 557606 | 543 | 0·442394 | 9 587941 | 625 | 0·412059 | 0·030335 | 81 | 9 969665 | 20 | 50 |
| 11 | 44 | 9 557932 | 543 | 0·442068 | 9 588316 | 625 | 0·411684 | 0·030384 | 82 | 9 969616 | 16 | 49 |
| 12 | 48 | 9·558258 | 543 | 0·441742 | 9 588691 | 624 | 0·411309 | 0·030433 | 82 | 9·969567 | 12 | 48 |
| 13 | 52 | 9·558583 | 542 | 0·441417 | 9·589066 | 624 | 0·410934 | 0·030482 | 82 | 9·969518 | 8 | 47 |
| 14 | 56 | 9·558909 | 542 | 0·441091 | 9·589440 | 623 | 0·410560 | 0·030531 | 82 | 9·969469 | 4 | 46 |
| 15 | **25** | 9 559234 | 541 | 0·440766 | 9·589814 | 623 | 0·410186 | 0·030580 | 82 | 9·969420 | **35** | 45 |
| 16 | 4 | 9·559558 | 541 | 0·440442 | 9·590188 | 623 | 0·409812 | 0·030630 | 82 | 9·969370 | 56 | 44 |
| 17 | 8 | 9·559883 | 540 | 0·440117 | 9 590562 | 622 | 0·409438 | 0·030679 | 82 | 9 969321 | 52 | 43 |
| 18 | 12 | 9·560207 | 540 | 0·439793 | 9 590935 | 622 | 0·409065 | 0·030728 | 82 | 9 969272 | 48 | 42 |
| 19 | 16 | 9·560531 | 539 | 0·439469 | 9·591308 | 622 | 0·408692 | 0·030777 | 82 | 9 969223 | 44 | 41 |
| 20 | 20 | 9·560855 | 539 | 0·439145 | 9 591681 | 621 | 0·408319 | 0·030827 | 82 | 9 969173 | 40 | 40 |
| 21 | 24 | 9·561178 | 538 | 0·438822 | 9·592054 | 621 | 0·407946 | 0·030876 | 82 | 9·969124 | 36 | 39 |
| 22 | 28 | 9 561501 | 538 | 0·438499 | 9 592426 | 620 | 0·407574 | 0·030925 | 82 | 9·969075 | 32 | 38 |
| 23 | 32 | 9·561824 | 537 | 0·438176 | 9 592799 | 620 | 0·407201 | 0·030975 | 82 | 9 969025 | 28 | 37 |
| 24 | 36 | 9·562146 | 537 | 0·437854 | 9 593171 | 619 | 0·406829 | 0·031024 | 83 | 9·968976 | 24 | 36 |
| 25 | 40 | 9·562468 | 536 | 0·437532 | 9 593542 | 619 | 0·406458 | 0·031074 | 83 | 9·968926 | 20 | 35 |
| 26 | 44 | 9·562790 | 536 | 0·437210 | 9·593914 | 618 | 0 406086 | 0·031123 | 83 | 9 968877 | 16 | 34 |
| 27 | 48 | 9·563112 | 536 | 0·436888 | 9 594285 | 618 | 0·405715 | 0·031173 | 83 | 9 968827 | 12 | 33 |
| 28 | 52 | 9·563433 | 535 | 0·436567 | 9 594656 | 618 | 0·405344 | 0·031223 | 83 | 9·968777 | 8 | 32 |
| 29 | 56 | 9·563755 | 535 | 0·436245 | 9 595027 | 617 | 0·404973 | 0·031272 | 83 | 9 968728 | 4 | 31 |
| 30 | **26** | 9·564075 | 534 | 0·435925 | 9·595398 | 617 | 0 404602 | 0·031322 | 83 | 9 968678 | **34** | 30 |
| 31 | 4 | 9 564396 | 534 | 0·435604 | 9 595768 | 617 | 0 404232 | 0·031372 | 83 | 9 968628 | 56 | 29 |
| 32 | 8 | 9·564716 | 533 | 0·435284 | 9 596138 | 616 | 0·403862 | 0·031422 | 83 | 9 968578 | 52 | 28 |
| 33 | 12 | 9·565036 | 533 | 0·434964 | 9 596508 | 616 | 0·403492 | 0·031472 | 83 | 9 968528 | 48 | 27 |
| 34 | 16 | 9·565356 | 532 | 0·434644 | 9 596878 | 616 | 0·403122 | 0·031521 | 83 | 9 968479 | 44 | 26 |
| 35 | 20 | 9 565676 | 532 | 0·434324 | 9 597247 | 615 | 0·402753 | 0 031571 | 83 | 9 968429 | 40 | 25 |
| 36 | 24 | 9·565995 | 531 | 0·434005 | 9 597616 | 615 | 0·402384 | 0 031621 | 83 | 9 968379 | 36 | 24 |
| 37 | 28 | 9·566314 | 531 | 0·433686 | 9 597985 | 615 | 0·402015 | 0·031671 | 83 | 9 968329 | 32 | 23 |
| 38 | 32 | 9·566632 | 531 | 0·433368 | 9 598354 | 614 | 0·401646 | 0·031722 | 83 | 9 968278 | 28 | 22 |
| 39 | 36 | 9·566951 | 530 | 0·433049 | 9 598722 | 614 | 0·401278 | 0·031772 | 84 | 9 968228 | 24 | 21 |
| 40 | 40 | 9·567269 | 530 | 0·432731 | 9·599091 | 613 | 0·400909 | 0·031822 | 84 | 9 968178 | 20 | 20 |
| 41 | 44 | 9·567587 | 529 | 0·432413 | 9 599459 | 613 | 0 400541 | 0 031872 | 84 | 9 968128 | 16 | 19 |
| 42 | 48 | 9·567904 | 529 | 0·432096 | 9 599827 | 613 | 0·400173 | 0·031922 | 84 | 9 968078 | 12 | 18 |
| 43 | 52 | 9·568222 | 528 | 0·431778 | 9 600194 | 612 | 0 399806 | 0·031973 | 84 | 9 968027 | 8 | 17 |
| 44 | 56 | 9·568539 | 528 | 0·431461 | 9 600562 | 612 | 0·399438 | 0·032023 | 84 | 9 967977 | 4 | 16 |
| 45 | **27** | 9·568856 | 528 | 0·431144 | 9 600929 | 611 | 0·399071 | 0·032073 | 84 | 9 967927 | **33** | 15 |
| 46 | 4 | 9·569172 | 527 | 0·430828 | 9·601296 | 611 | 0·398704 | 0·032124 | 84 | 9 967876 | 56 | 14 |
| 47 | 8 | 9·569488 | 527 | 0·430512 | 9 601663 | 611 | 0 398337 | 0·032174 | 84 | 9 967826 | 52 | 13 |
| 48 | 12 | 9·569804 | 526 | 0·430196 | 9 602029 | 610 | 0·397971 | 0·032225 | 84 | 9 967775 | 48 | 12 |
| 49 | 16 | 9·570120 | 526 | 0·429880 | 9 602395 | 610 | 0 397605 | 0 032275 | 84 | 9 967725 | 44 | 11 |
| 50 | 20 | 9·570435 | 525 | 0·429565 | 9 602761 | 610 | 0 397239 | 0·032326 | 84 | 9 967674 | 40 | 10 |
| 51 | 24 | 9·570751 | 525 | 0·429249 | 9 603127 | 609 | 0 396873 | 0 032376 | 84 | 9 967624 | 36 | 9 |
| 52 | 28 | 9 571066 | 524 | 0·428934 | 9 603493 | 609 | 0·396507 | 0·032427 | 84 | 9 967573 | 32 | 8 |
| 53 | 32 | 9·571380 | 524 | 0·428620 | 9 603858 | 609 | 0·396142 | 0 032478 | 85 | 9 967522 | 28 | 7 |
| 54 | 36 | 9·571695 | 523 | 0·428305 | 9 604223 | 608 | 0 395777 | 0 032529 | 85 | 9 967471 | 24 | 6 |
| 55 | 40 | 9·572009 | 523 | 0·427991 | 9 604588 | 608 | 0·395412 | 0·032579 | 85 | 9 967421 | 20 | 5 |
| 56 | 44 | 9·572323 | 523 | 0·427677 | 9 604953 | 607 | 0·395047 | 0·032630 | 85 | 9 967370 | 16 | 4 |
| 57 | 48 | 9·572636 | 522 | 0·427364 | 9 605317 | 607 | 0·394683 | 0 032681 | 85 | 9 967319 | 12 | 3 |
| 58 | 52 | 9·572950 | 522 | 0·427050 | 9 605682 | 607 | 0 394318 | 0·032732 | 85 | 9 967268 | 8 | 2 |
| 59 | 56 | 9·573263 | 521 | 0·426737 | 9 606046 | 606 | 0·393954 | 0·032783 | 85 | 9 967217 | 4 | 1 |
| 60 | **28** | 9·573575 | | 0·426425 | 9 606410 | | 0·393590 | 0 032834 | | 9 967166 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent | Cosec. | D. | Sine. | M. s. | ′ |

111° 68°=4h 32m 68°

## LOG. SINES, COSINES, &c.

22° 22°=1h 28m 157°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9 573575 | 521 | 0·426425 | 9·606410 | 606 | 0·393590 | 0·032834 | 85 | 9·967166 | **32** | 60 |
| 1 | 4 | 9 573888 | 520 | 0·426112 | 9 606773 | 606 | 0 393227 | 0·032885 | 85 | 9 967115 | 56 | 59 |
| 2 | 8 | 9 574200 | 520 | 0·425800 | 9 607137 | 605 | 0·392863 | 0·032936 | 85 | 9 967064 | 52 | 58 |
| 3 | 12 | 9 574512 | 519 | 0·425488 | 9 607500 | 605 | 0·392500 | 0 032987 | 85 | 9 967013 | 48 | 57 |
| 4 | 16 | 9 574824 | 519 | 0·425176 | 9 607863 | 604 | 0 392137 | 0·033039 | 85 | 9 966961 | 44 | 56 |
| 5 | 20 | 9 575136 | 519 | 0·424864 | 9 608225 | 604 | 0 391775 | 0·033090 | 85 | 9 966910 | 40 | 55 |
| 6 | 24 | 9 575447 | 518 | 0 424553 | 9 608588 | 604 | 0 391412 | 0·033141 | 85 | 9 966859 | 36 | 54 |
| 7 | 28 | 9 575758 | 518 | 0·424242 | 9 608950 | 603 | 0 391050 | 0·033192 | 85 | 9 966808 | 32 | 53 |
| 8 | 32 | 9 576069 | 517 | 0·423931 | 9 609312 | 603 | 0·390688 | 0 033244 | 86 | 9 966756 | 28 | 52 |
| 9 | 36 | 9 576379 | 517 | 0·423621 | 9 609674 | 603 | 0·390326 | 0·033295 | 86 | 9 966705 | 24 | 51 |
| 10 | 40 | 9 576689 | 516 | 0 423311 | 9 610036 | 602 | 0 389964 | 0 033347 | 86 | 9 966653 | 20 | 50 |
| 11 | 44 | 9 576999 | 516 | 0 423001 | 9 610397 | 602 | 0 389603 | 0·033398 | 86 | 9 966602 | 16 | 49 |
| 12 | 48 | 9·577309 | 516 | 0·422691 | 9 610759 | 602 | 0 389241 | 0 033450 | 86 | 9 966550 | 12 | 48 |
| 13 | 52 | 9 577618 | 515 | 0·422382 | 9·611120 | 601 | 0·388880 | 0·033501 | 86 | 9 966499 | 8 | 47 |
| 14 | 56 | 9 577927 | 515 | 0 422073 | 9 611480 | 601 | 0 388520 | 0·033553 | 86 | 9 966447 | 4 | 46 |
| 15 | **29** | 9 578236 | 514 | 0 421764 | 9 611841 | 601 | 0·388159 | 0·033605 | 86 | 9 966395 | **31** | 45 |
| 16 | 4 | 9 578545 | 514 | 0 421455 | 9 612201 | 600 | 0·387799 | 0 033656 | 86 | 9·966344 | 56 | 44 |
| 17 | 8 | 9·578853 | 513 | 0 421147 | 9 612561 | 600 | 0 387439 | 0 033708 | 86 | 9 966292 | 52 | 43 |
| 18 | 12 | 9 579162 | 513 | 0·420838 | 9 612921 | 600 | 0·387079 | 0·033760 | 86 | 9·966240 | 48 | 42 |
| 19 | 16 | 9 579470 | 513 | 0·420530 | 9 613281 | 599 | 0·386719 | 0 033812 | 86 | 9 966188 | 44 | 41 |
| 20 | 20 | 9 579777 | 512 | 0 420223 | 9 613641 | 599 | 0·386359 | 0·033864 | 86 | 9 966136 | 40 | 40 |
| 21 | 24 | 9·580085 | 512 | 0 419915 | 9 614000 | 598 | 0 386000 | 0 033915 | 87 | 9 966085 | 36 | 39 |
| 22 | 28 | 9 580392 | 511 | 0 419608 | 9 614359 | 598 | 0 385641 | 0·033967 | 87 | 9·966033 | 32 | 38 |
| 23 | 32 | 9 580699 | 511 | 0·419301 | 9 614718 | 598 | 0·385282 | 0·034019 | 87 | 9 965981 | 28 | 37 |
| 24 | 36 | 9 581005 | 511 | 0·418995 | 9 615077 | 597 | 0 384923 | 0 034071 | 87 | 9·965929 | 24 | 36 |
| 25 | 40 | 9·581312 | 510 | 0·418688 | 9 615435 | 597 | 0 384565 | 0·034124 | 87 | 9·965876 | 20 | 35 |
| 26 | 44 | 9·581618 | 510 | 0·418382 | 9 615793 | 597 | 0 384207 | 0·034176 | 87 | 9 965824 | 16 | 34 |
| 27 | 48 | 9 581924 | 509 | 0·418076 | 9 616151 | 596 | 0·383849 | 0·034228 | 87 | 9 965772 | 12 | 33 |
| 28 | 52 | 9·582229 | 509 | 0·417771 | 9 616509 | 596 | 0·383491 | 0·034280 | 87 | 9·965720 | 8 | 32 |
| 29 | 56 | 9 582535 | 509 | 0·417465 | 9·616867 | 596 | 0·383133 | 0·034332 | 87 | 9·965668 | 4 | 31 |
| 30 | **30** | 9·582840 | 508 | 0·417160 | 9 617224 | 595 | 0·382776 | 0·034385 | 87 | 9 965615 | **30** | 30 |
| 31 | 4 | 9 583145 | 508 | 0·416855 | 9 617582 | 595 | 0 382418 | 0 034437 | 87 | 9·965563 | 56 | 29 |
| 32 | 8 | 9 583449 | 507 | 0·416551 | 9 617939 | 595 | 0·382061 | 0·034489 | 87 | 9 965511 | 52 | 28 |
| 33 | 12 | 9·583754 | 507 | 0·416246 | 9 618295 | 594 | 0·381705 | 0·034542 | 87 | 9 965458 | 48 | 27 |
| 34 | 16 | 9 584058 | 506 | 0·415942 | 9·618652 | 594 | 0·381348 | 0 034594 | 87 | 9 965406 | 44 | 26 |
| 35 | 20 | 9 584361 | 506 | 0·415639 | 9 619008 | 594 | 0·380992 | 0·034647 | 88 | 9 965353 | 40 | 25 |
| 36 | 24 | 9·584665 | 506 | 0·415335 | 9 619364 | 593 | 0 380636 | 0·034699 | 88 | 9 965301 | 36 | 24 |
| 37 | 28 | 9 584968 | 505 | 0·415032 | 9 619720 | 593 | 0·380280 | 0·034752 | 88 | 9 965248 | 32 | 23 |
| 38 | 32 | 9·585272 | 505 | 0·414728 | 9 620076 | 593 | 0·379924 | 0·034805 | 88 | 9·965195 | 28 | 22 |
| 39 | 36 | 9·585574 | 504 | 0·414426 | 9 620432 | 592 | 0·379568 | 0·034857 | 88 | 9·965143 | 24 | 21 |
| 40 | 40 | 9·585877 | 504 | 0·414123 | 9 620787 | 592 | 0·379213 | 0·034910 | 88 | 9 965090 | 20 | 20 |
| 41 | 44 | 9·586179 | 503 | 0·413821 | 9 621142 | 592 | 0·378858 | 0 034963 | 88 | 9 965037 | 16 | 19 |
| 42 | 48 | 9 586482 | 503 | 0·413518 | 9 621497 | 591 | 0·378503 | 0·035016 | 88 | 9·964984 | 12 | 18 |
| 43 | 52 | 9·586783 | 503 | 0·413217 | 9·621852 | 591 | 0 378148 | 0·035069 | 88 | 9 964931 | 8 | 17 |
| 44 | 56 | 9 587085 | 502 | 0·412915 | 9 622207 | 590 | 0·377793 | 0·035121 | 88 | 9 964879 | 4 | 16 |
| 45 | **31** | 9 587386 | 502 | 0·412614 | 9 622561 | 590 | 0·377439 | 0·035174 | 88 | 9 964826 | **29** | 15 |
| 46 | 4 | 9 587688 | 501 | 0·412312 | 9·622915 | 590 | 0·377085 | 0·035227 | 88 | 9 964773 | 56 | 14 |
| 47 | 8 | 9·587989 | 501 | 0·412011 | 9 623269 | 589 | 0·376731 | 0·035280 | 88 | 9 964720 | 52 | 13 |
| 48 | 12 | 9·588289 | 501 | 0·411711 | 9·623623 | 589 | 0·376377 | 0·035334 | 89 | 9 964666 | 48 | 12 |
| 49 | 16 | 9·588590 | 500 | 0·411410 | 9 623976 | 589 | 0·376024 | 0·035387 | 89 | 9 964613 | 44 | 11 |
| 50 | 20 | 9·588890 | 500 | 0·411110 | 9·624330 | 588 | 0·375670 | 0·035440 | 89 | 9 964560 | 40 | 10 |
| 51 | 24 | 9·589190 | 499 | 0·410810 | 9 624683 | 588 | 0·375317 | 0·035493 | 89 | 9 964507 | 36 | 9 |
| 52 | 28 | 9 589489 | 499 | 0·410511 | 9 625036 | 588 | 0·374964 | 0·035546 | 89 | 9·964454 | 32 | 8 |
| 53 | 32 | 9 589789 | 499 | 0·410211 | 9 625388 | 587 | 0·374612 | 0·035600 | 89 | 9·964400 | 28 | 7 |
| 54 | 36 | 9·590088 | 498 | 0·409912 | 9 625741 | 587 | 0·374259 | 0·035653 | 89 | 9·964347 | 24 | 6 |
| 55 | 40 | 9 590387 | 498 | 0·409613 | 9·626093 | 587 | 0·373907 | 0·035706 | 89 | 9 964294 | 20 | 5 |
| 56 | 44 | 9 590686 | 497 | 0·409314 | 9·626445 | 586 | 0·373555 | 0·035760 | 89 | 9 964240 | 16 | 4 |
| 57 | 48 | 9·590984 | 497 | 0·409016 | 9·626797 | 586 | 0·373203 | 0·035813 | 89 | 9·964187 | 12 | 3 |
| 58 | 52 | 9·591282 | 497 | 0·408718 | 9·627149 | 586 | 0·372851 | 0·035867 | 89 | 9·964133 | 8 | 2 |
| 59 | 56 | 9·591580 | 496 | 0·408420 | 9 627501 | 585 | 0·372499 | 0·035920 | 89 | 9·964080 | 4 | 1 |
| 60 | **32** | 9 591878 | | 0·408122 | 9 627852 | | 0·372148 | 0·035974 | | 9 964026 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

112° 67°=4h 28m 67°

LOG. SINES, COSINES, &c.

23° 23°=1h 32m 156°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·591878 | 496 | 0·408122 | 9 627852 | 585 | 0·372148 | 0 035974 | 89 | 9 964026 | 28 | 60 |
| 1 | 4 | 9·592176 | 495 | 0·407824 | 9 628203 | 585 | 0 371797 | 0 036028 | 89 | 9 963972 | 56 | 59 |
| 2 | 8 | 9·592473 | 495 | 0 407527 | 9·628554 | 585 | 0 371446 | 0 036081 | 89 | 9 963919 | 52 | 58 |
| 3 | 12 | 9·592770 | 495 | 0 407230 | 9 628905 | 584 | 0 371095 | 0 036135 | 90 | 9 963865 | 48 | 57 |
| 4 | 16 | 9 593067 | 494 | 0·406933 | 9 629255 | 584 | 0 370745 | 0 036189 | 90 | 9 963811 | 44 | 56 |
| 5 | 20 | 9 593363 | 494 | 0 406637 | 9 629606 | 583 | 0 370394 | 0 036243 | 90 | 9 963757 | 40 | 55 |
| 6 | 24 | 9 593659 | 493 | 0 406341 | 9 629956 | 583 | 0 370044 | 0 036296 | 90 | 9 963704 | 36 | 54 |
| 7 | 28 | 9 593955 | 493 | 0·406045 | 9 630306 | 583 | 0 369694 | 0 036350 | 90 | 9 963650 | 32 | 53 |
| 8 | 32 | 9 594251 | 493 | 0·405749 | 9 630656 | 583 | 0 369344 | 0 036404 | 90 | 9 963596 | 28 | 52 |
| 9 | 36 | 9 594547 | 492 | 0·405453 | 9 631005 | 582 | 0 368995 | 0 036458 | 90 | 9 963542 | 24 | 51 |
| 10 | 40 | 9·594842 | 492 | 0 405158 | 9 631355 | 582 | 0 368645 | 0 036512 | 90 | 9 963488 | 20 | 50 |
| 11 | 44 | 9·595137 | 491 | 0 404863 | 9 631704 | 582 | 0 368296 | 0 036566 | 90 | 9 963434 | 16 | 49 |
| 12 | 48 | 9 595432 | 491 | 0·404568 | 9 632053 | 581 | 0 367947 | 0 036621 | 90 | 9 963379 | 12 | 48 |
| 13 | 52 | 9 595727 | 491 | 0 404273 | 9 632402 | 581 | 0 367598 | 0 036675 | 90 | 9 963325 | 8 | 47 |
| 14 | 56 | 9·596021 | 490 | 0 403979 | 9 632750 | 581 | 0 367250 | 0 036729 | 90 | 9 963271 | 4 | 46 |
| 15 | 33 | 9 596315 | 490 | 0 403685 | 9 633099 | 580 | 0 366901 | 0 036783 | 90 | 9 963217 | 27 | 45 |
| 16 | 4 | 9 596609 | 489 | 0·403391 | 9 633447 | 580 | 0·366553 | 0 036837 | 90 | 9 963163 | 56 | 44 |
| 17 | 8 | 9 596903 | 489 | 0·403097 | 9 633795 | 580 | 0 366205 | 0 036892 | 91 | 9 963108 | 52 | 43 |
| 18 | 12 | 9 597196 | 489 | 0 402804 | 9 634143 | 579 | 0 365857 | 0 036946 | 91 | 9 963054 | 48 | 42 |
| 19 | 16 | 9 597490 | 488 | 0 402510 | 9 634490 | 579 | 0 365510 | 0 037001 | 91 | 9 962999 | 44 | 41 |
| 20 | 20 | 9 597783 | 488 | 0 402217 | 9 634838 | 579 | 0 365162 | 0 037055 | 91 | 9 962945 | 40 | 40 |
| 21 | 24 | 9·598075 | 487 | 0 401925 | 9 635185 | 578 | 0 364815 | 0 037110 | 91 | 9 962890 | 36 | 39 |
| 22 | 28 | 9 598368 | 487 | 0 401632 | 9 635532 | 578 | 0 364468 | 0 037164 | 91 | 9 962836 | 32 | 38 |
| 23 | 32 | 9·598660 | 487 | 0 401340 | 9 635879 | 578 | 0 364121 | 0·037219 | 91 | 9 962781 | 28 | 37 |
| 24 | 36 | 9 598952 | 486 | 0 401048 | 9 636226 | 577 | 0 363774 | 0.037273 | 91 | 9 962727 | 24 | 36 |
| 25 | 40 | 9·599244 | 486 | 0 400756 | 9 636572 | 577 | 0 363428 | 0 037328 | 91 | 9 962672 | 20 | 35 |
| 26 | 44 | 9·599536 | 485 | 0·400464 | 9 636919 | 577 | 0 363081 | 0 037383 | 91 | 9 962617 | 16 | 34 |
| 27 | 48 | 9 599827 | 485 | 0·400173 | 9 637265 | 577 | 0 362735 | 0 037438 | 91 | 9 962562 | 12 | 33 |
| 28 | 52 | 9 600118 | 485 | 0·399882 | 9 637611 | 576 | 0 362389 | 0 037492 | 91 | 9 962508 | 8 | 32 |
| 29 | 56 | 9 600409 | 484 | 0 399591 | 9 637956 | 576 | 0 362044 | 0 037547 | 91 | 9 962453 | 4 | 31 |
| 30 | 34 | 9·600700 | 484 | 0·399300 | 9 638302 | 576 | 0 361698 | 0 037602 | 92 | 9 962398 | 26 | 30 |
| 31 | 4 | 9 600990 | 484 | 0·399010 | 9 638647 | 575 | 0 361353 | 0 037657 | 92 | 9 962343 | 56 | 29 |
| 32 | 8 | 9 601280 | 483 | 0 398720 | 9 638992 | 575 | 0 361008 | 0 037712 | 92 | 9 962288 | 52 | 28 |
| 33 | 12 | 9 601570 | 483 | 0·398430 | 9 639337 | 575 | 0 360663 | 0 037767 | 92 | 9 962233 | 48 | 27 |
| 34 | 16 | 9 601860 | 482 | 0·398140 | 9 639682 | 574 | 0 360318 | 0 037822 | 92 | 9 962178 | 44 | 26 |
| 35 | 20 | 9 602150 | 482 | 0 397850 | 9 640027 | 574 | 0 359973 | 0 037877 | 92 | 9 962123 | 40 | 25 |
| 36 | 24 | 9 602439 | 482 | 0 397561 | 9 640371 | 574 | 0 359629 | 0 037933 | 92 | 9 962067 | 36 | 24 |
| 37 | 28 | 9 602728 | 481 | 0·397272 | 9 640716 | 573 | 0 359284 | 0·037988 | 92 | 9 962012 | 32 | 23 |
| 38 | 32 | 9 603017 | 481 | 0·396983 | 9 641060 | 573 | 0 358940 | 0·038043 | 92 | 9 961957 | 28 | 22 |
| 39 | 36 | 9·603305 | 481 | 0·396695 | 9 641404 | 573 | 0 358596 | 0 038098 | 92 | 9·961902 | 24 | 21 |
| 40 | 40 | 9·603594 | 480 | 0·396406 | 9 641747 | 572 | 0 358253 | 0 038154 | 92 | 9 961846 | 20 | 20 |
| 41 | 44 | 9 603882 | 480 | 0·396118 | 9 642091 | 572 | 0 357909 | 0 038209 | 92 | 9 961791 | 16 | 19 |
| 42 | 48 | 9·604170 | 479 | 0·395830 | 9 642434 | 572 | 0 357566 | 0 038265 | 92 | 9 961735 | 12 | 18 |
| 43 | 52 | 9·604457 | 479 | 0 395543 | 9 642777 | 572 | 0 357223 | 0 038320 | 92 | 9 961680 | 8 | 17 |
| 44 | 56 | 9 604745 | 479 | 0 395255 | 9 643120 | 571 | 0 356880 | 0 038376 | 93 | 9 961624 | 4 | 16 |
| 45 | 35 | 9·605032 | 478 | 0 394968 | 9 643463 | 571 | 0 356537 | 0 038431 | 93 | 9 961569 | 25 | 15 |
| 46 | 4 | 9·605319 | 478 | 0·394681 | 9 643806 | 571 | 0 356194 | 0 038487 | 93 | 9 961513 | 56 | 14 |
| 47 | 8 | 9·605606 | 478 | 0·394394 | 9 644148 | 570 | 0 355852 | 0·038542 | 93 | 9 961458 | 52 | 13 |
| 48 | 12 | 9·605892 | 477 | 0·394108 | 9·644490 | 570 | 0 355510 | 0 038598 | 93 | 9 961402 | 48 | 12 |
| 49 | 16 | 9·606179 | 477 | 0·393821 | 9 644832 | 570 | 0 355168 | 0 038654 | 93 | 9 961346 | 44 | 11 |
| 50 | 20 | 9·606465 | 476 | 0·393535 | 9 645174 | 569 | 0·354826 | 0·038710 | 93 | 9 961290 | 40 | 10 |
| 51 | 24 | 9 606751 | 476 | 0·393249 | 9 645516 | 569 | 0 354484 | 0 038765 | 93 | 9·961235 | 36 | 9 |
| 52 | 28 | 9 607036 | 476 | 0·392964 | 9 645857 | 569 | 0 354143 | 0 038821 | 93 | 9 961179 | 32 | 8 |
| 53 | 32 | 9 607322 | 475 | 0 392678 | 9 646199 | 569 | 0 353801 | 0 038877 | 93 | 9·961123 | 28 | 7 |
| 54 | 36 | 9·607607 | 475 | 0 392393 | 9 646540 | 568 | 0·353460 | 0·038933 | 93 | 9·961067 | 24 | 6 |
| 55 | 40 | 9·607892 | 474 | 0 392108 | 9·646881 | 568 | 0·353119 | 0·038989 | 93 | 9 961011 | 20 | 5 |
| 56 | 44 | 9·608177 | 474 | 0 391823 | 9·647222 | 568 | 0·352778 | 0 039045 | 93 | 9 960955 | 16 | 4 |
| 57 | 48 | 9·608461 | 474 | 0·391539 | 9·647562 | 567 | 0·352438 | 0·039101 | 93 | 9·960899 | 12 | 3 |
| 58 | 52 | 9·608745 | 473 | 0·391255 | 9 647903 | 567 | 0·352097 | 0·039157 | 94 | 9·960843 | 8 | 2 |
| 59 | 56 | 9·609029 | 473 | 0·390971 | 9 648243 | 567 | 0·351757 | 0·039214 | 94 | 9·960786 | 4 | 1 |
| 60 | 36 | 9·609313 | 473 | 0·390687 | 9 648583 | 567 | 0·351417 | 0·039270 | 94 | 9·960730 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

113° 66°=4h 24m 66°

## LOG. SINES, COSINES, &c.

24° 24°=1h 36m 155°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·609313 | 473 | 0·390687 | 9·648583 | 566 | 0·351417 | 0·039270 | 94 | 9·960730 | **24** | 60 |
| 1 | 4 | 9·609597 | 472 | 0·390403 | 9·648923 | 566 | 0·351077 | 0·039326 | 94 | 9·960674 | 56 | 59 |
| 2 | 8 | 9·609880 | 472 | 0·390120 | 9·649263 | 566 | 0·350737 | 0·039382 | 94 | 9·960618 | 52 | 58 |
| 3 | 12 | 9·610164 | 472 | 0·389836 | 9·649602 | 566 | 0·350398 | 0·039439 | 94 | 9·960561 | 48 | 57 |
| 4 | 16 | 9·610447 | 471 | 0·389553 | 9·649942 | 565 | 0·350058 | 0·039495 | 94 | 9·960505 | 44 | 56 |
| 5 | 20 | 9·610729 | 471 | 0·389271 | 9·650281 | 565 | 0·349719 | 0·039552 | 94 | 9·960448 | 40 | 55 |
| 6 | 24 | 9·611012 | 470 | 0·388988 | 9·650620 | 565 | 0·349380 | 0·039608 | 94 | 9·960392 | 36 | 54 |
| 7 | 28 | 9·611294 | 470 | 0·388706 | 9·650959 | 564 | 0·349041 | 0·039665 | 94 | 9·960335 | 32 | 53 |
| 8 | 32 | 9·611576 | 470 | 0·388424 | 9·651297 | 564 | 0·348703 | 0·039721 | 94 | 9·960279 | 28 | 52 |
| 9 | 36 | 9·611858 | 469 | 0·388142 | 9·651636 | 564 | 0·348364 | 0·039778 | 94 | 9·960222 | 24 | 51 |
| 10 | 40 | 9·612140 | 469 | 0·387860 | 9·651974 | 563 | 0·348026 | 0·039835 | 94 | 9·960165 | 20 | 50 |
| 11 | 44 | 9·612421 | 469 | 0·387579 | 9·652312 | 563 | 0·347688 | 0·039891 | 95 | 9·960109 | 16 | 49 |
| 12 | 48 | 9·612702 | 468 | 0·387298 | 9·652650 | 563 | 0·347350 | 0·039948 | 95 | 9·960052 | 12 | 48 |
| 13 | 52 | 9·612983 | 468 | 0·387017 | 9·652988 | 563 | 0·347012 | 0·040005 | 95 | 9·959995 | 8 | 47 |
| 14 | 56 | 9·613264 | 467 | 0·386736 | 9·653326 | 562 | 0·346674 | 0·040062 | 95 | 9·959938 | 4 | 46 |
| 15 | **37** | 9·613545 | 467 | 0·386455 | 9·653663 | 562 | 0·346337 | 0·040118 | 95 | 9·959882 | **23** | 45 |
| 16 | 4 | 9·613825 | 467 | 0·386175 | 9·654000 | 562 | 0·346000 | 0·040175 | 95 | 9·959825 | 56 | 44 |
| 17 | 8 | 9·614105 | 466 | 0·385895 | 9·654337 | 561 | 0·345663 | 0·040232 | 95 | 9·959768 | 52 | 43 |
| 18 | 12 | 9·614385 | 466 | 0·385615 | 9·654674 | 561 | 0·345326 | 0·040289 | 95 | 9·959711 | 48 | 42 |
| 19 | 16 | 9·614665 | 466 | 0·385335 | 9·655011 | 561 | 0·344989 | 0·040346 | 95 | 9·959654 | 44 | 41 |
| 20 | 20 | 9·614944 | 465 | 0·385056 | 9·655348 | 561 | 0·344652 | 0·040404 | 95 | 9·959596 | 40 | 40 |
| 21 | 24 | 9·615223 | 465 | 0·384777 | 9·655684 | 560 | 0·344316 | 0·040461 | 95 | 9·959539 | 36 | 39 |
| 22 | 28 | 9·615502 | 465 | 0·384498 | 9·656020 | 560 | 0·343980 | 0·040518 | 95 | 9·959482 | 32 | 38 |
| 23 | 32 | 9·615781 | 464 | 0·384219 | 9·656356 | 560 | 0·343644 | 0·040575 | 95 | 9·959425 | 28 | 37 |
| 24 | 36 | 9·616060 | 464 | 0·383940 | 9·656692 | 559 | 0·343308 | 0·040632 | 95 | 9·959368 | 24 | 36 |
| 25 | 40 | 9·616338 | 464 | 0·383662 | 9·657028 | 559 | 0·342972 | 0·040690 | 96 | 9·959310 | 20 | 35 |
| 26 | 44 | 9·616616 | 463 | 0·383384 | 9·657364 | 559 | 0·342636 | 0·040747 | 96 | 9·959253 | 16 | 34 |
| 27 | 48 | 9·616894 | 463 | 0·383106 | 9·657699 | 559 | 0·342301 | 0·040805 | 96 | 9·959195 | 12 | 33 |
| 28 | 52 | 9·617172 | 462 | 0·382828 | 9·658034 | 558 | 0·341966 | 0·040862 | 96 | 9·959138 | 8 | 32 |
| 29 | 56 | 9·617450 | 462 | 0·382550 | 9·658369 | 558 | 0·341631 | 0·040919 | 96 | 9·959080 | 4 | 31 |
| 30 | **38** | 9·617727 | 462 | 0·382273 | 9·658704 | 558 | 0·341296 | 0·040977 | 96 | 9·959023 | **22** | 30 |
| 31 | 4 | 9·618004 | 461 | 0·381996 | 9·659039 | 558 | 0·340961 | 0·041035 | 96 | 9·958965 | 56 | 29 |
| 32 | 8 | 9·618281 | 461 | 0·381719 | 9·659373 | 557 | 0·340627 | 0·041092 | 96 | 9·958908 | 52 | 28 |
| 33 | 12 | 9·618558 | 461 | 0·381442 | 9·659708 | 557 | 0·340292 | 0·041150 | 96 | 9·958850 | 48 | 27 |
| 34 | 16 | 9·618834 | 460 | 0·381166 | 9·660042 | 557 | 0·339958 | 0·041208 | 96 | 9·958792 | 44 | 26 |
| 35 | 20 | 9·619110 | 460 | 0·380890 | 9·660376 | 557 | 0·339624 | 0·041266 | 96 | 9·958734 | 40 | 25 |
| 36 | 24 | 9·619386 | 460 | 0·380614 | 9·660710 | 556 | 0·339290 | 0·041323 | 96 | 9·958677 | 36 | 24 |
| 37 | 28 | 9·619662 | 459 | 0·380338 | 9·661043 | 556 | 0·338957 | 0·041381 | 96 | 9·958619 | 32 | 23 |
| 38 | 32 | 9·619938 | 459 | 0·380062 | 9·661377 | 556 | 0·338623 | 0·041439 | 96 | 9·958561 | 28 | 22 |
| 39 | 36 | 9·620213 | 459 | 0·379787 | 9·661710 | 555 | 0·338290 | 0·041497 | 97 | 9·958503 | 24 | 21 |
| 40 | 40 | 9·620488 | 458 | 0·379512 | 9·662043 | 555 | 0·337957 | 0·041555 | 97 | 9·958445 | 20 | 20 |
| 41 | 44 | 9·620763 | 458 | 0·379237 | 9·662376 | 555 | 0·337624 | 0·041613 | 97 | 9·958387 | 16 | 19 |
| 42 | 48 | 9·621038 | 457 | 0·378962 | 9·662709 | 554 | 0·337291 | 0·041671 | 97 | 9·958329 | 12 | 18 |
| 43 | 52 | 9·621313 | 457 | 0·378687 | 9·663042 | 554 | 0·336958 | 0·041729 | 97 | 9·958271 | 8 | 17 |
| 44 | 56 | 9·621587 | 457 | 0·378413 | 9·663375 | 554 | 0·336625 | 0·041787 | 97 | 9·958213 | 4 | 16 |
| 45 | **39** | 9·621861 | 456 | 0·378139 | 9·663707 | 554 | 0·336293 | 0·041846 | 97 | 9·958154 | **21** | 15 |
| 46 | 4 | 9·622135 | 456 | 0·377865 | 9·664039 | 553 | 0·335961 | 0·041904 | 97 | 9·958096 | 56 | 14 |
| 47 | 8 | 9·622409 | 456 | 0·377591 | 9·664371 | 553 | 0·335629 | 0·041962 | 97 | 9·958038 | 52 | 13 |
| 48 | 12 | 9·622682 | 456 | 0·377318 | 9·664703 | 553 | 0·335297 | 0·042021 | 97 | 9·957979 | 48 | 12 |
| 49 | 16 | 9·622956 | 455 | 0·377044 | 9·665035 | 553 | 0·334965 | 0·042079 | 97 | 9·957921 | 44 | 11 |
| 50 | 20 | 9·623229 | 455 | 0·376771 | 9·665366 | 552 | 0·334634 | 0·042137 | 97 | 9·957863 | 40 | 10 |
| 51 | 24 | 9·623502 | 454 | 0·376498 | 9·665698 | 552 | 0·334302 | 0·042196 | 97 | 9·957804 | 36 | 9 |
| 52 | 28 | 9·623774 | 454 | 0·376226 | 9·666029 | 552 | 0·333971 | 0·042254 | 98 | 9·957746 | 32 | 8 |
| 53 | 32 | 9·624047 | 454 | 0·375953 | 9·666360 | 551 | 0·333640 | 0·042313 | 98 | 9·957687 | 28 | 7 |
| 54 | 36 | 9·624319 | 453 | 0·375681 | 9·666691 | 551 | 0·333309 | 0·042372 | 98 | 9·957628 | 24 | 6 |
| 55 | 40 | 9·624591 | 453 | 0·375409 | 9·667021 | 551 | 0·332979 | 0·042430 | 98 | 9·957570 | 20 | 5 |
| 56 | 44 | 9·624863 | 453 | 0·375137 | 9·667352 | 551 | 0·332648 | 0·042489 | 98 | 9·957511 | 16 | 4 |
| 57 | 48 | 9·625135 | 452 | 0·374865 | 9·667682 | 550 | 0·332318 | 0·042548 | 98 | 9·957452 | 12 | 3 |
| 58 | 52 | 9·625406 | 452 | 0·374594 | 9·668013 | 550 | 0·331987 | 0·042607 | 98 | 9·957393 | 8 | 2 |
| 59 | 56 | 9·625677 | 452 | 0·374323 | 9·668343 | 550 | 0·331657 | 0·042665 | 98 | 9·957335 | 4 | 1 |
| 60 | **40** | 9·625948 | 452 | 0·374052 | 9·668673 | 550 | 0·331327 | 0·042724 | 98 | 9·957276 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

114° 65°=4h 20m 65°

## LOG. SINES, COSINES, &c.

25° 25°=1h 40m 154°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·625948 | 451 | 0·374052 | 9 668673 | 550 | 0 331327 | 0 042724 | 98 | 9 957276 | **20** | 60 |
| 1 | 4 | 9·626219 | 451 | 0·373781 | 9 669002 | 549 | 0 330998 | 0 042783 | 98 | 9 957217 | 56 | 59 |
| 2 | 8 | 9·626490 | 451 | 0 373510 | 9 669332 | 549 | 0 330668 | 0·042842 | 98 | 9 957158 | 52 | 58 |
| 3 | 12 | 9·626760 | 450 | 0 373240 | 9 669661 | 549 | 0·330339 | 0·042901 | 98 | 9 957099 | 48 | 57 |
| 4 | 16 | 9 627030 | 450 | 0·372970 | 9 669991 | 548 | 0 330009 | 0·042960 | 98 | 9 957040 | 44 | 56 |
| 5 | 20 | 9 627300 | 450 | 0·372700 | 9 670320 | 548 | 0 329680 | 0·043019 | 98 | 9 956981 | 40 | 55 |
| 6 | 24 | 9·627570 | 449 | 0·372430 | 9 670649 | 548 | 0 329351 | 0·043079 | 99 | 9 956921 | 36 | 54 |
| 7 | 28 | 9 627840 | 449 | 0·372160 | 9 670977 | 548 | 0 329023 | 0 043138 | 99 | 9 956862 | 32 | 53 |
| 8 | 32 | 9·628109 | 449 | 0·371891 | 9 671306 | 547 | 0·328694 | 0 043197 | 99 | 9 956803 | 28 | 52 |
| 9 | 36 | 9 628378 | 448 | 0·371622 | 9 671635 | 547 | 0·328365 | 0 043256 | 99 | 9 956744 | 24 | 51 |
| 10 | 40 | 9·628647 | 448 | 0·371353 | 9 671963 | 547 | 0 328037 | 0 043316 | 99 | 9 956684 | 20 | 50 |
| 11 | 44 | 9 628916 | 447 | 0·371084 | 9 672291 | 547 | 0 327709 | 0·043375 | 99 | 9 956625 | 16 | 49 |
| 12 | 48 | 9·629185 | 447 | 0·370815 | 9 672619 | 546 | 0·327381 | 0 043434 | 99 | 9 956566 | 12 | 48 |
| 13 | 52 | 9·629453 | 447 | 0·370547 | 9 672947 | 546 | 0 327053 | 0 043494 | 99 | 9 956506 | 8 | 47 |
| 14 | 56 | 9 629721 | 446 | 0·370279 | 9 673274 | 546 | 0·326726 | 0 043553 | 99 | 9 956447 | 4 | 46 |
| 15 | **41** | 9·629989 | 446 | 0·370011 | 9 673602 | 546 | 0·326398 | 0 043613 | 99 | 9 956387 | **19** | 45 |
| 16 | 4 | 9·630257 | 446 | 0·369743 | 9 673929 | 545 | 0·326071 | 0 043673 | 99 | 9 956327 | 56 | 44 |
| 17 | 8 | 9·630524 | 446 | 0·369476 | 9 674257 | 545 | 0 325743 | 0 043732 | 99 | 9 956268 | 52 | 43 |
| 18 | 12 | 9·630792 | 445 | 0·369208 | 9 674584 | 545 | 0·325416 | 0 043792 | 100 | 9 956208 | 48 | 42 |
| 19 | 16 | 9·631059 | 445 | 0·368941 | 9 674911 | 544 | 0·325089 | 0 043852 | 100 | 9 956148 | 44 | 41 |
| 20 | 20 | 9·631326 | 445 | 0 368674 | 9 675237 | 544 | 0·324763 | 0 043911 | 100 | 9 956089 | 40 | 40 |
| 21 | 24 | 9·631593 | 444 | 0·368407 | 9 675564 | 544 | 0 324436 | 0 043971 | 100 | 9 956029 | 36 | 39 |
| 22 | 28 | 9·631859 | 444 | 0·368141 | 9 675890 | 544 | 0·324110 | 0 044031 | 100 | 9 955969 | 32 | 38 |
| 23 | 32 | 9·632125 | 444 | 0·367875 | 9 676217 | 543 | 0·323783 | 0 044091 | 100 | 9 955909 | 28 | 37 |
| 24 | 36 | 9·632392 | 444 | 0·367608 | 9 676543 | 543 | 0·323457 | 0.044151 | 100 | 9 955849 | 24 | 36 |
| 25 | 40 | 9·632658 | 443 | 0·367342 | 9 676869 | 543 | 0 323131 | 0 044211 | 100 | 9·955789 | 20 | 35 |
| 26 | 44 | 9·632923 | 443 | 0·367077 | 9 677194 | 543 | 0 322806 | 0 044271 | 100 | 9 955729 | 16 | 34 |
| 27 | 48 | 9·633189 | 443 | 0·366811 | 9 677520 | 542 | 0 322480 | 0·044331 | 100 | 9 955669 | 12 | 33 |
| 28 | 52 | 9·633454 | 442 | 0·366546 | 9 677846 | 542 | 0 322154 | 0 044391 | 100 | 9 955609 | 8 | 32 |
| 29 | 56 | 9·633719 | 442 | 0·366281 | 9·678171 | 542 | 0·321829 | 0 044452 | 100 | 9 955548 | 4 | 31 |
| 30 | **42** | 9·633984 | 441 | 0·366016 | 9 678496 | 542 | 0 321504 | 0 044512 | 100 | 9 955488 | **18** | 30 |
| 31 | 4 | 9·634249 | 441 | 0·365751 | 9 678821 | 541 | 0·321179 | 0 044572 | 101 | 9 955428 | 56 | 29 |
| 32 | 8 | 9 634514 | 440 | 0·365486 | 9 679146 | 541 | 0 320854 | 0 044632 | 101 | 9·955368 | 52 | 28 |
| 33 | 12 | 9·634778 | 440 | 0·365222 | 9 679471 | 541 | 0·320529 | 0 044693 | 101 | 9 955307 | 48 | 27 |
| 34 | 16 | 9 635042 | 440 | 0·364958 | 9 679795 | 541 | 0 320205 | 0 044753 | 101 | 9 955247 | 44 | 26 |
| 35 | 20 | 9·635306 | 440 | 0·364694 | 9 680120 | 540 | 0·319880 | 0 044814 | 101 | 9 955186 | 40 | 25 |
| 36 | 24 | 9·635570 | 439 | 0·364430 | 9 680444 | 540 | 0·319556 | 0 044874 | 101 | 9 955126 | 36 | 24 |
| 37 | 28 | 9·635834 | 439 | 0·364166 | 9·680768 | 540 | 0·319232 | 0·044935 | 101 | 9 955065 | 32 | 23 |
| 38 | 32 | 9·636097 | 439 | 0·363903 | 9 681092 | 540 | 0·318908 | 0 044995 | 101 | 9 955005 | 28 | 22 |
| 39 | 36 | 9·636360 | 438 | 0·363640 | 9 681416 | 539 | 0 318584 | 0·045056 | 101 | 9 954944 | 24 | 21 |
| 40 | 40 | 9·636623 | 438 | 0·363377 | 9 681740 | 539 | 0 318260 | 0·045117 | 101 | 9 954883 | 20 | 20 |
| 41 | 44 | 9·636886 | 437 | 0·363114 | 9 682063 | 539 | 0·317937 | 0·045177 | 101 | 9 954823 | 16 | 19 |
| 42 | 48 | 9·637148 | 437 | 0·362852 | 9 682387 | 539 | 0·317613 | 0·045238 | 101 | 9 954762 | 12 | 18 |
| 43 | 52 | 9·637411 | 437 | 0·362589 | 9 682710 | 538 | 0·317290 | 0·045299 | 101 | 9 954701 | 8 | 17 |
| 44 | 56 | 9·637673 | 437 | 0·362327 | 9 683033 | 538 | 0·316967 | 0·045360 | 101 | 9 954640 | 4 | 16 |
| 45 | **43** | 9·637935 | 436 | 0·362065 | 9 683356 | 538 | 0·316644 | 0·045421 | 101 | 9 954579 | **17** | 15 |
| 46 | 4 | 9·638197 | 436 | 0·361803 | 9·683679 | 538 | 0·316321 | 0·045482 | 102 | 9 954518 | 56 | 14 |
| 47 | 8 | 9·638458 | 436 | 0·361542 | 9 684001 | 537 | 0·315999 | 0·045543 | 102 | 9 954457 | 52 | 13 |
| 48 | 12 | 9·638720 | 435 | 0·361280 | 9·684324 | 537 | 0·315676 | 0·045604 | 102 | 9 954396 | 48 | 12 |
| 49 | 16 | 9·638981 | 435 | 0·361019 | 9 684646 | 537 | 0·315354 | 0·045665 | 102 | 9 954335 | 44 | 11 |
| 50 | 20 | 9·639242 | 435 | 0·360758 | 9·684968 | 537 | 0·315032 | 0·045726 | 102 | 9 954274 | 40 | 10 |
| 51 | 24 | 9·639503 | 434 | 0·360497 | 9 685290 | 536 | 0·314710 | 0·045787 | 102 | 9 954213 | 36 | 9 |
| 52 | 28 | 9·639764 | 434 | 0·360236 | 9 685612 | 536 | 0·314388 | 0·045848 | 102 | 9 954152 | 32 | 8 |
| 53 | 32 | 9·640024 | 434 | 0·359976 | 9 685934 | 536 | 0·314066 | 0·045910 | 102 | 9·954090 | 28 | 7 |
| 54 | 36 | 9·640284 | 433 | 0·359716 | 9 686255 | 536 | 0·313745 | 0·045971 | 102 | 9·954029 | 24 | 6 |
| 55 | 40 | 9·640544 | 433 | 0·359456 | 9·686577 | 535 | 0·313423 | 0·046032 | 102 | 9 953968 | 20 | 5 |
| 56 | 44 | 9·640804 | 433 | 0·359196 | 9·686898 | 535 | 0·313102 | 0·046094 | 102 | 9 953906 | 16 | 4 |
| 57 | 48 | 9·641064 | 432 | 0·358936 | 9 687219 | 535 | 0·312781 | 0·046155 | 102 | 9·953845 | 12 | 3 |
| 58 | 52 | 9·641324 | 432 | 0·358676 | 9·687540 | 535 | 0·312460 | 0·046217 | 102 | 9·953783 | 8 | 2 |
| 59 | 56 | 9·641583 | 432 | 0·358417 | 9·687861 | 534 | 0·312139 | 0·046278 | 102 | 9·953722 | 4 | 1 |
| 60 | **44** | 9·641842 | | 0·358158 | 9·688182 | | 0·311818 | 0·046340 | | 9·953660 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

115° 64°=4h 16m 64°

## LOG. SINES, COSINES, &c.

26° | 26°=1h 44m | 153°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·641842 | 431 | 0·358158 | 9·688182 | 534 | 0·311818 | 0·046340 | 103 | 9·953660 | 16 | 60 |
| 1 | 4 | 9·642101 | 431 | 0·357899 | 9 688502 | 534 | 0·311498 | 0·046401 | 103 | 9 953599 | 56 | 59 |
| 2 | 8 | 9·642360 | 431 | 0·357640 | 9 688823 | 534 | 0·311177 | 0·046463 | 103 | 9 953537 | 52 | 58 |
| 3 | 12 | 9·642618 | 430 | 0·357382 | 9·689143 | 533 | 0·310857 | 0·046525 | 103 | 9 953475 | 48 | 57 |
| 4 | 16 | 9 642877 | 430 | 0·357123 | 9 689463 | 533 | 0·310537 | 0·046587 | 103 | 9 953413 | 44 | 56 |
| 5 | 20 | 9·643135 | 430 | 0·356865 | 9 689783 | 533 | 0·310217 | 0·046648 | 103 | 9 953352 | 40 | 55 |
| 6 | 24 | 9·643393 | 430 | 0·356607 | 9 690103 | 533 | 0·309897 | 0·046710 | 103 | 9 953290 | 36 | 54 |
| 7 | 28 | 9 643650 | 429 | 0·356350 | 9 690423 | 533 | 0·309577 | 0·046772 | 103 | 9 953228 | 32 | 53 |
| 8 | 32 | 9·643908 | 429 | 0·356092 | 9 690742 | 532 | 0·309258 | 0·046834 | 103 | 9 953166 | 28 | 52 |
| 9 | 36 | 9·644165 | 429 | 0·355835 | 9 691062 | 532 | 0·308938 | 0·046896 | 103 | 9 953104 | 24 | 51 |
| 10 | 40 | 9·644423 | 428 | 0·355577 | 9 691381 | 532 | 0·308619 | 0 046958 | 103 | 9 953042 | 20 | 50 |
| 11 | 44 | 9 644680 | 428 | 0·355320 | 9 691700 | 531 | 0·308300 | 0·047020 | 104 | 9·952980 | 16 | 49 |
| 12 | 48 | 9·644936 | 428 | 0·355064 | 9 692019 | 531 | 0·307981 | 0 047082 | 104 | 9·952918 | 12 | 48 |
| 13 | 52 | 9·645193 | 427 | 0·354807 | 9·692338 | 531 | 0·307662 | 0 047145 | 104 | 9 952855 | 8 | 47 |
| 14 | 56 | 9 645450 | 427 | 0 354550 | 9 692656 | 531 | 0·307344 | 0·047207 | 104 | 9 952793 | 4 | 46 |
| 15 | **45** | 9 645706 | 427 | 0·354294 | 9 692975 | 531 | 0·307025 | 0·047269 | 104 | 9 952731 | **15** | 45 |
| 16 | 4 | 9·645962 | 426 | 0·354038 | 9 693293 | 530 | 0·306707 | 0·047331 | 104 | 9 952669 | 56 | 44 |
| 17 | 8 | 9 646218 | 426 | 0·353782 | 9 693612 | 530 | 0 306388 | 0 047394 | 104 | 9 952606 | 52 | 43 |
| 18 | 12 | 9·646474 | 426 | 0·353526 | 9 693930 | 530 | 0·306070 | 0 047456 | 104 | 9 952544 | 48 | 42 |
| 19 | 16 | 9·646729 | 426 | 0·353271 | 9 694248 | 530 | 0·305752 | 0 047519 | 104 | 9 952481 | 44 | 41 |
| 20 | 20 | 9·646984 | 425 | 0 353016 | 9 694566 | 529 | 0 305434 | 0·047581 | 104 | 9 952419 | 40 | 40 |
| 21 | 24 | 9·647240 | 425 | 0·352760 | 9·694883 | 529 | 0·305117 | 0 047644 | 104 | 9 952356 | 36 | 39 |
| 22 | 28 | 9·647494 | 424 | 0 352506 | 9 695201 | 529 | 0 304799 | 0·047706 | 104 | 9 952294 | 32 | 38 |
| 23 | 32 | 9·647749 | 424 | 0 352251 | 9 695518 | 529 | 0·304482 | 0·047769 | 104 | 9 952231 | 28 | 37 |
| 24 | 36 | 9·648004 | 424 | 0·351996 | 9 695836 | 529 | 0·304164 | 0.047832 | 105 | 9 952168 | 24 | 36 |
| 25 | 40 | 9·648258 | 424 | 0·351742 | 9 696153 | 528 | 0·303847 | 0·047894 | 105 | 9 952106 | 20 | 35 |
| 26 | 44 | 9·648512 | 423 | 0·351488 | 9 696470 | 528 | 0 303530 | 0 047957 | 105 | 9 952043 | 16 | 34 |
| 27 | 48 | 9·648766 | 423 | 0·351234 | 9 696787 | 528 | 0·303213 | 0·048020 | 105 | 9·951980 | 12 | 33 |
| 28 | 52 | 9·649020 | 423 | 0·350980 | 9 697103 | 528 | 0 302897 | 0 048083 | 105 | 9 951917 | 8 | 32 |
| 29 | 56 | 9 649274 | 422 | 0 350726 | 9 697420 | 527 | 0·302580 | 0·048146 | 105 | 9 951854 | 4 | 31 |
| 30 | **46** | 9·649527 | 422 | 0·350473 | 9 697736 | 527 | 0 302264 | 0 048209 | 105 | 9 951791 | **14** | 30 |
| 31 | 4 | 9·649781 | 422 | 0·350219 | 9 698053 | 527 | 0 301947 | 0 048272 | 105 | 9 951728 | 56 | 29 |
| 32 | 8 | 9 650034 | 422 | 0·349966 | 9 698369 | 527 | 0 301631 | 0 048335 | 105 | 9·951665 | 52 | 28 |
| 33 | 12 | 9·650287 | 421 | 0·349713 | 9 698685 | 526 | 0·301315 | 0 048398 | 105 | 9 951602 | 48 | 27 |
| 34 | 16 | 9 650539 | 421 | 0 349461 | 9 699001 | 526 | 0·300999 | 0·048461 | 105 | 9 951539 | 44 | 26 |
| 35 | 20 | 9 650792 | 421 | 0 349208 | 9 699316 | 526 | 0·300684 | 0 048524 | 105 | 9 951476 | 40 | 25 |
| 36 | 24 | 9·651044 | 420 | 0·348956 | 9 699632 | 526 | 0 300368 | 0 048588 | 105 | 9 951412 | 36 | 24 |
| 37 | 28 | 9 651297 | 420 | 0·348703 | 9 699947 | 526 | 0 300053 | 0·048651 | 106 | 9 951349 | 32 | 23 |
| 38 | 32 | 9·651549 | 420 | 0·348451 | 9 700263 | 525 | 0 299737 | 0·048714 | 106 | 9 951286 | 28 | 22 |
| 39 | 36 | 9·651800 | 419 | 0·348200 | 9·700578 | 525 | 0·299422 | 0·048778 | 106 | 9 951222 | 24 | 21 |
| 40 | 40 | 9·652052 | 419 | 0·347948 | 9 700893 | 525 | 0 299107 | 0 048841 | 106 | 9 951159 | 20 | 20 |
| 41 | 44 | 9·652304 | 419 | 0·347696 | 9 701208 | 524 | 0 298792 | 0 048904 | 106 | 9·951096 | 16 | 19 |
| 42 | 48 | 9·652555 | 418 | 0·347445 | 9 701523 | 524 | 0·298477 | 0 048968 | 106 | 9 951032 | 12 | 18 |
| 43 | 52 | 9·652806 | 418 | 0 347194 | 9·701837 | 524 | 0·298163 | 0·049032 | 106 | 9 950968 | 8 | 17 |
| 44 | 56 | 9·653057 | 418 | 0·346943 | 9·702152 | 524 | 0 297848 | 0·049095 | 106 | 9 950905 | 4 | 16 |
| 45 | **47** | 9·653308 | 418 | 0·346692 | 9 702466 | 524 | 0 297534 | 0 049159 | 106 | 9 950841 | **13** | 15 |
| 46 | 4 | 9·653558 | 417 | 0·346442 | 9·702781 | 523 | 0 297219 | 0 049222 | 106 | 9 950778 | 56 | 14 |
| 47 | 8 | 9·653808 | 417 | 0·346192 | 9 703095 | 523 | 0·296905 | 0 049286 | 106 | 9 950714 | 52 | 13 |
| 48 | 12 | 9·654059 | 417 | 0 345941 | 9·703409 | 523 | 0 296591 | 0 049350 | 106 | 9·950650 | 48 | 12 |
| 49 | 16 | 9·654309 | 416 | 0·345691 | 9 703722 | 523 | 0·296278 | 0·049414 | 106 | 9 950586 | 44 | 11 |
| 50 | 20 | 9·654558 | 416 | 0·345442 | 9·704036 | 522 | 0 295964 | 0·049478 | 107 | 9 950522 | 40 | 10 |
| 51 | 24 | 9 654808 | 416 | 0·345192 | 9 704350 | 522 | 0·295650 | 0·049542 | 107 | 9 950458 | 36 | 9 |
| 52 | 28 | 9·655058 | 416 | 0·344942 | 9·704663 | 522 | 0·295337 | 0·049606 | 107 | 9 950394 | 32 | 8 |
| 53 | 32 | 9 655307 | 415 | 0·344693 | 9·704976 | 522 | 0 295024 | 0 049670 | 107 | 9 950330 | 28 | 7 |
| 54 | 36 | 9·655556 | 415 | 0 344444 | 9 705290 | 522 | 0 294710 | 0 049734 | 107 | 9·950266 | 24 | 6 |
| 55 | 40 | 9 655805 | 415 | 0·344195 | 9 705603 | 521 | 0·294397 | 0·049798 | 107 | 9 950202 | 20 | 5 |
| 56 | 44 | 9·656054 | 414 | 0·343946 | 9·705916 | 521 | 0·294084 | 0·049862 | 107 | 9 950138 | 16 | 4 |
| 57 | 48 | 9·656302 | 414 | 0·343698 | 9·706228 | 521 | 0·293772 | 0·049926 | 107 | 9·950074 | 12 | 3 |
| 58 | 52 | 9·656551 | 414 | 0·343449 | 9 706541 | 521 | 0·293459 | 0 049990 | 107 | 9 950010 | 8 | 2 |
| 59 | 56 | 9·656799 | 413 | 0·343201 | 9·706854 | 521 | 0·293146 | 0 050055 | 107 | 9·949945 | 4 | 1 |
| 60 | **48** | 9·657047 | | 0·342953 | 9·707166 | | 0·292834 | 0 050119 | | 9 949881 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

116° | 63°=4h 12m | 63°

## LOG. SINES, COSINES, &c.

27° 27°=1h 48m 152°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·657047 | 413 | 0·342953 | 9·707166 | 520 | 0·292834 | 0·050119 | 107 | 9·949881 | 12 | 60 |
| 1 | 4 | 9·657295 | 413 | 0·342705 | 9·707478 | 520 | 0·292522 | 0·050184 | 107 | 9·949816 | 56 | 59 |
| 2 | 8 | 9·657542 | 412 | 0·342458 | 9·707790 | 520 | 0·292210 | 0·050248 | 107 | 9·949752 | 52 | 58 |
| 3 | 12 | 9·657790 | 412 | 0·342210 | 9·708102 | 520 | 0·291898 | 0·050312 | 108 | 9·949688 | 48 | 57 |
| 4 | 16 | 9·658037 | 412 | 0·341963 | 9·708414 | 519 | 0·291586 | 0·050377 | 108 | 9·949623 | 44 | 56 |
| 5 | 20 | 9·658284 | 412 | 0·341716 | 9·708726 | 519 | 0·291274 | 0·050442 | 108 | 9·949558 | 40 | 55 |
| 6 | 24 | 9·658531 | 411 | 0·341469 | 9·709037 | 519 | 0·290963 | 0·050506 | 108 | 9·949494 | 36 | 54 |
| 7 | 28 | 9·658778 | 411 | 0·341222 | 9·709349 | 519 | 0·290651 | 0·050571 | 108 | 9·949429 | 32 | 53 |
| 8 | 32 | 9·659025 | 411 | 0·340975 | 9·709660 | 519 | 0·290340 | 0·050636 | 108 | 9·949364 | 28 | 52 |
| 9 | 36 | 9·659271 | 410 | 0·340729 | 9·709971 | 518 | 0·290029 | 0·050700 | 108 | 9·949300 | 24 | 51 |
| 10 | 40 | 9·659517 | 410 | 0·340483 | 9·710282 | 518 | 0·289718 | 0·050765 | 108 | 9·949235 | 20 | 50 |
| 11 | 44 | 9·659763 | 410 | 0·340237 | 9·710593 | 518 | 0·289407 | 0·050830 | 108 | 9·949170 | 16 | 49 |
| 12 | 48 | 9·660009 | 409 | 0·339991 | 9·710904 | 518 | 0·289096 | 0·050895 | 108 | 9·949105 | 12 | 48 |
| 13 | 52 | 9·660255 | 409 | 0·339745 | 9·711215 | 518 | 0·288785 | 0·050960 | 108 | 9·949040 | 8 | 47 |
| 14 | 56 | 9·660501 | 409 | 0·339499 | 9·711525 | 517 | 0·288475 | 0·051025 | 108 | 9·948975 | 4 | 46 |
| 15 | 49 | 9·660746 | 409 | 0·339254 | 9·711836 | 517 | 0·288164 | 0·051090 | 108 | 9·948910 | 11 | 45 |
| 16 | 4 | 9·660991 | 408 | 0·339009 | 9·712146 | 517 | 0·287854 | 0·051155 | 108 | 9·948845 | 56 | 44 |
| 17 | 8 | 9·661236 | 408 | 0·338764 | 9·712456 | 517 | 0·287544 | 0·051220 | 109 | 9·948780 | 52 | 43 |
| 18 | 12 | 9·661481 | 408 | 0·338519 | 9·712766 | 516 | 0·287234 | 0·051285 | 109 | 9·948715 | 48 | 42 |
| 19 | 16 | 9·661726 | 407 | 0·338274 | 9·713076 | 516 | 0·286924 | 0·051350 | 109 | 9·948650 | 44 | 41 |
| 20 | 20 | 9·661970 | 407 | 0·338030 | 9·713386 | 516 | 0·286614 | 0·051416 | 109 | 9·948584 | 40 | 40 |
| 21 | 24 | 9·662214 | 407 | 0·337786 | 9·713696 | 516 | 0·286304 | 0·051481 | 109 | 9·948519 | 36 | 39 |
| 22 | 28 | 9·662459 | 407 | 0·337541 | 9·714005 | 516 | 0·285995 | 0·051546 | 109 | 9·948454 | 32 | 38 |
| 23 | 32 | 9·662703 | 406 | 0·337297 | 9·714314 | 515 | 0·285686 | 0·051612 | 109 | 9·948388 | 28 | 37 |
| 24 | 36 | 9·662946 | 406 | 0·337054 | 9·714624 | 515 | 0·285376 | 0·051677 | 109 | 9·948323 | 24 | 36 |
| 25 | 40 | 9·663190 | 406 | 0·336810 | 9·714933 | 515 | 0·285067 | 0·051743 | 109 | 9·948257 | 20 | 35 |
| 26 | 44 | 9·663433 | 405 | 0·336567 | 9·715242 | 515 | 0·284758 | 0·051808 | 109 | 9·948192 | 16 | 34 |
| 27 | 48 | 9·663677 | 405 | 0·336323 | 9·715551 | 514 | 0·284449 | 0·051874 | 109 | 9·948126 | 12 | 33 |
| 28 | 52 | 9·663920 | 405 | 0·336080 | 9·715860 | 514 | 0·284140 | 0·051940 | 109 | 9·948060 | 8 | 32 |
| 29 | 56 | 9·664163 | 405 | 0·335837 | 9·716168 | 514 | 0·283832 | 0·052005 | 110 | 9·947995 | 4 | 31 |
| 30 | 50 | 9·664406 | 404 | 0·335594 | 9·716477 | 514 | 0·283523 | 0·052071 | 110 | 9·947929 | 10 | 30 |
| 31 | 4 | 9·664648 | 404 | 0·335352 | 9·716785 | 514 | 0·283215 | 0·052137 | 110 | 9·947863 | 56 | 29 |
| 32 | 8 | 9·664891 | 404 | 0·335109 | 9·717093 | 513 | 0·282907 | 0·052203 | 110 | 9·947797 | 52 | 28 |
| 33 | 12 | 9·665133 | 403 | 0·334867 | 9·717401 | 513 | 0·282599 | 0·052269 | 110 | 9·947731 | 48 | 27 |
| 34 | 16 | 9·665375 | 403 | 0·334625 | 9·717709 | 513 | 0·282291 | 0·052335 | 110 | 9·947665 | 44 | 26 |
| 35 | 20 | 9·665617 | 403 | 0·334383 | 9·718017 | 513 | 0·281983 | 0·052400 | 110 | 9·947600 | 40 | 25 |
| 36 | 24 | 9·665859 | 402 | 0·334141 | 9·718325 | 513 | 0·281675 | 0·052467 | 110 | 9·947533 | 36 | 24 |
| 37 | 28 | 9·666100 | 402 | 0·333900 | 9·718633 | 512 | 0·281367 | 0·052533 | 110 | 9·947467 | 32 | 23 |
| 38 | 32 | 9·666342 | 402 | 0·333658 | 9·718940 | 512 | 0·281060 | 0·052599 | 110 | 9·947401 | 28 | 22 |
| 39 | 36 | 9·666583 | 402 | 0·333417 | 9·719248 | 512 | 0·280752 | 0·052665 | 110 | 9·947335 | 24 | 21 |
| 40 | 40 | 9·666824 | 401 | 0·333176 | 9·719555 | 512 | 0·280445 | 0·052731 | 110 | 9·947269 | 20 | 20 |
| 41 | 44 | 9·667065 | 401 | 0·332935 | 9·719862 | 512 | 0·280138 | 0·052797 | 110 | 9·947203 | 16 | 19 |
| 42 | 48 | 9·667305 | 401 | 0·332695 | 9·720169 | 511 | 0·279831 | 0·052864 | 111 | 9·947136 | 12 | 18 |
| 43 | 52 | 9·667546 | 401 | 0·332454 | 9·720476 | 511 | 0·279524 | 0·052930 | 111 | 9·947070 | 8 | 17 |
| 44 | 56 | 9·667786 | 400 | 0·332214 | 9·720783 | 511 | 0·279217 | 0·052996 | 111 | 9·947004 | 4 | 16 |
| 45 | 51 | 9·668027 | 400 | 0·331973 | 9·721089 | 511 | 0·278911 | 0·053063 | 111 | 9·946937 | 9 | 15 |
| 46 | 4 | 9·668267 | 400 | 0·331733 | 9·721396 | 511 | 0·278604 | 0·053129 | 111 | 9·946871 | 56 | 14 |
| 47 | 8 | 9·668506 | 400 | 0·331494 | 9·721702 | 510 | 0·278298 | 0·053196 | 111 | 9·946804 | 52 | 13 |
| 48 | 12 | 9·668746 | 399 | 0·331254 | 9·722009 | 510 | 0·277991 | 0·053262 | 111 | 9·946738 | 48 | 12 |
| 49 | 16 | 9·668986 | 399 | 0·331014 | 9·722315 | 510 | 0·277685 | 0·053329 | 111 | 9·946671 | 44 | 11 |
| 50 | 20 | 9·669225 | 399 | 0·330775 | 9·722621 | 510 | 0·277379 | 0·053396 | 111 | 9·946604 | 40 | 10 |
| 51 | 24 | 9·669464 | 398 | 0·330536 | 9·722927 | 510 | 0·277073 | 0·053462 | 111 | 9·946538 | 36 | 9 |
| 52 | 28 | 9·669703 | 398 | 0·330297 | 9·723232 | 509 | 0·276768 | 0·053529 | 111 | 9·946471 | 32 | 8 |
| 53 | 32 | 9·669942 | 398 | 0·330058 | 9·723538 | 509 | 0·276462 | 0·053596 | 111 | 9·946404 | 28 | 7 |
| 54 | 36 | 9·670181 | 397 | 0·329819 | 9·723844 | 509 | 0·276156 | 0·053663 | 111 | 9·946337 | 24 | 6 |
| 55 | 40 | 9·670419 | 397 | 0·329581 | 9·724149 | 509 | 0·275851 | 0·053730 | 112 | 9·946270 | 20 | 5 |
| 56 | 44 | 9·670658 | 397 | 0·329342 | 9·724454 | 509 | 0·275546 | 0·053797 | 112 | 9·946203 | 16 | 4 |
| 57 | 48 | 9·670896 | 397 | 0·329104 | 9·724760 | 508 | 0·275240 | 0·053864 | 112 | 9·946136 | 12 | 3 |
| 58 | 52 | 9·671134 | 396 | 0·328866 | 9·725065 | 508 | 0·274935 | 0·053931 | 112 | 9·946069 | 8 | 2 |
| 59 | 56 | 9·671372 | 396 | 0·328628 | 9·725370 | 508 | 0·274630 | 0·053998 | 112 | 9·946002 | 4 | 1 |
| 60 | 52 | 9·671609 | 396 | 0·328391 | 9·725674 | 508 | 0·274326 | 0·054065 | 112 | 9·945935 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

117° 62°=4h 8m 62°

## LOG. SINES, COSINES, &c.

28° 28°=1h 52m 151°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·671609 | 396 | 0·328391 | 9·725674 | 508 | 0·274326 | 0·054065 | 112 | 9·945935 | 8 | 60 |
| 1 | 4 | 9·671847 | 395 | 0·328153 | 9·725979 | 508 | 0·274021 | 0·054132 | 112 | 9 945868 | 56 | 59 |
| 2 | 8 | 9·672084 | 395 | 0·327916 | 9·726284 | 507 | 0·273716 | 0·054200 | 112 | 9·945800 | 52 | 58 |
| 3 | 12 | 9·672321 | 395 | 0·327679 | 9·726588 | 507 | 0·273412 | 0·054267 | 112 | 9 945733 | 48 | 57 |
| 4 | 16 | 9·672558 | 395 | 0·327442 | 9·726892 | 507 | 0·273108 | 0·054334 | 112 | 9 945666 | 44 | 56 |
| 5 | 20 | 9·672795 | 394 | 0·327205 | 9·727197 | 507 | 0·272803 | 0·054402 | 112 | 9 945598 | 40 | 55 |
| 6 | 24 | 9·673032 | 394 | 0·326968 | 9·727501 | 507 | 0·272499 | 0·054469 | 112 | 9·945531 | 36 | 54 |
| 7 | 28 | 9·673268 | 394 | 0·326732 | 9·727805 | 506 | 0·272195 | 0·054536 | 113 | 9 945464 | 32 | 53 |
| 8 | 32 | 9·673505 | 394 | 0·326495 | 9·728109 | 506 | 0·271891 | 0·054604 | 113 | 9 945396 | 28 | 52 |
| 9 | 36 | 9·673741 | 393 | 0·326259 | 9·728412 | 506 | 0·271588 | 0·054672 | 113 | 9 945328 | 24 | 51 |
| 10 | 40 | 9·673977 | 393 | 0·326023 | 9·728716 | 506 | 0·271284 | 0·054739 | 113 | 9·945261 | 20 | 50 |
| 11 | 44 | 9·674213 | 393 | 0·325787 | 9·729020 | 506 | 0·270980 | 0·054807 | 113 | 9·945193 | 16 | 49 |
| 12 | 48 | 9·674448 | 392 | 0·325552 | 9·729323 | 505 | 0·270677 | 0·054875 | 113 | 9·945125 | 12 | 48 |
| 13 | 52 | 9·674684 | 392 | 0·325316 | 9·729626 | 505 | 0·270374 | 0·054942 | 113 | 9·945058 | 8 | 47 |
| 14 | 56 | 9·674919 | 392 | 0·325081 | 9·729929 | 505 | 0·270071 | 0·055010 | 113 | 9·944990 | 4 | 46 |
| 15 | **53** | 9·675155 | 392 | 0·324845 | 9·730233 | 505 | 0·269767 | 0·055078 | 113 | 9·944922 | **7** | 45 |
| 16 | 4 | 9·675390 | 391 | 0·324610 | 9·730535 | 505 | 0·269465 | 0·055146 | 113 | 9·944854 | 56 | 44 |
| 17 | 8 | 9·675624 | 391 | 0·324376 | 9·730838 | 504 | 0·269162 | 0·055214 | 113 | 9·944786 | 52 | 43 |
| 18 | 12 | 9·675859 | 391 | 0·324141 | 9·731141 | 504 | 0·268859 | 0·055282 | 113 | 9·944718 | 48 | 42 |
| 19 | 16 | 9·676094 | 391 | 0·323906 | 9·731444 | 504 | 0·268556 | 0·055350 | 113 | 9·944650 | 44 | 41 |
| 20 | 20 | 9·676328 | 390 | 0·323672 | 9·731746 | 504 | 0·268254 | 0·055418 | 114 | 9·944582 | 40 | 40 |
| 21 | 24 | 9·676562 | 390 | 0·323438 | 9·732048 | 504 | 0·267952 | 0·055486 | 114 | 9·944514 | 36 | 39 |
| 22 | 28 | 9·676796 | 390 | 0·323204 | 9·732351 | 503 | 0·267649 | 0·055554 | 114 | 9·944446 | 32 | 38 |
| 23 | 32 | 9·677030 | 390 | 0·322970 | 9·732653 | 503 | 0·267347 | 0·055623 | 114 | 9·944377 | 28 | 37 |
| 24 | 36 | 9·677264 | 389 | 0·322736 | 9·732955 | 503 | 0·267045 | 0·055691 | 114 | 9·944309 | 24 | 36 |
| 25 | 40 | 9·677498 | 389 | 0·322502 | 9·733257 | 503 | 0·266743 | 0·055759 | 114 | 9·944241 | 20 | 35 |
| 26 | 44 | 9·677731 | 389 | 0·322269 | 9·733558 | 503 | 0·266442 | 0·055828 | 114 | 9·944172 | 16 | 34 |
| 27 | 48 | 9·677964 | 388 | 0·322036 | 9·733860 | 502 | 0·266140 | 0·055896 | 114 | 9·944104 | 12 | 33 |
| 28 | 52 | 9·678197 | 388 | 0·321803 | 9·734162 | 502 | 0·265838 | 0·055964 | 114 | 9·944036 | 8 | 32 |
| 29 | 56 | 9·678430 | 388 | 0·321570 | 9·734463 | 502 | 0·265537 | 0·056033 | 114 | 9·943967 | 4 | 31 |
| 30 | **54** | 9·678663 | 388 | 0·321337 | 9·734764 | 502 | 0·265236 | 0·056101 | 114 | 9·943899 | **6** | 30 |
| 31 | 4 | 9·678895 | 387 | 0·321105 | 9·735066 | 502 | 0·264934 | 0·056170 | 114 | 9·943830 | 56 | 29 |
| 32 | 8 | 9·679128 | 387 | 0·320872 | 9·735367 | 502 | 0·264633 | 0·056239 | 114 | 9·943761 | 52 | 28 |
| 33 | 12 | 9·679360 | 387 | 0·320640 | 9·735668 | 501 | 0·264332 | 0·056307 | 115 | 9·943693 | 48 | 27 |
| 34 | 16 | 9·679592 | 387 | 0·320408 | 9·735969 | 501 | 0·264031 | 0·056376 | 115 | 9·943624 | 44 | 26 |
| 35 | 20 | 9·679824 | 386 | 0·320176 | 9·736269 | 501 | 0·263731 | 0·056445 | 115 | 9·943555 | 40 | 25 |
| 36 | 24 | 9·680056 | 386 | 0·319944 | 9·736570 | 501 | 0·263430 | 0·056514 | 115 | 9·943486 | 36 | 24 |
| 37 | 28 | 9·680288 | 386 | 0·319712 | 9·736871 | 501 | 0·263129 | 0·056583 | 115 | 9·943417 | 32 | 23 |
| 38 | 32 | 9·680519 | 385 | 0·319481 | 9·737171 | 500 | 0·262829 | 0·056652 | 115 | 9·943348 | 28 | 22 |
| 39 | 36 | 9·680750 | 385 | 0·319250 | 9·737471 | 500 | 0·262529 | 0·056721 | 115 | 9·943279 | 24 | 21 |
| 40 | 40 | 9·680982 | 385 | 0·319018 | 9·737771 | 500 | 0·262229 | 0·056790 | 115 | 9·943210 | 20 | 20 |
| 41 | 44 | 9·681213 | 385 | 0·318787 | 9·738071 | 500 | 0·261929 | 0·056859 | 115 | 9·943141 | 16 | 19 |
| 42 | 48 | 9·681443 | 384 | 0·318557 | 9 738371 | 500 | 0·261629 | 0·056928 | 115 | 9·943072 | 12 | 18 |
| 43 | 52 | 9·681674 | 384 | 0·318326 | 9·738671 | 499 | 0·261329 | 0·056997 | 115 | 9·943003 | 8 | 17 |
| 44 | 56 | 9·681905 | 384 | 0·318095 | 9·738971 | 499 | 0·261029 | 0·057066 | 115 | 9·942934 | 4 | 16 |
| 45 | **55** | 9·682135 | 384 | 0·317865 | 9·739271 | 499 | 0·260729 | 0·057136 | 115 | 9·942864 | **5** | 15 |
| 46 | 4 | 9·682365 | 383 | 0·317635 | 9·739570 | 499 | 0·260430 | 0·057205 | 116 | 9·942795 | 56 | 14 |
| 47 | 8 | 9·682595 | 383 | 0·317405 | 9·739870 | 499 | 0·260130 | 0·057274 | 116 | 9·942726 | 52 | 13 |
| 48 | 12 | 9·682825 | 383 | 0·317175 | 9·740169 | 499 | 0·259831 | 0·057344 | 116 | 9·942656 | 48 | 12 |
| 49 | 16 | 9·683055 | 383 | 0·316945 | 9·740468 | 498 | 0·259532 | 0·057413 | 116 | 9·942587 | 44 | 11 |
| 50 | 20 | 9·683284 | 382 | 0·316716 | 9·740767 | 498 | 0·259233 | 0·057483 | 116 | 9·942517 | 40 | 10 |
| 51 | 24 | 9·683514 | 382 | 0·316486 | 9·741066 | 498 | 0·258934 | 0·057552 | 116 | 9·942448 | 36 | 9 |
| 52 | 28 | 9·683743 | 382 | 0·316257 | 9·741365 | 498 | 0·258635 | 0·057622 | 116 | 9·942378 | 32 | 8 |
| 53 | 32 | 9 683972 | 382 | 0·316028 | 9·741664 | 498 | 0·258336 | 0·057692 | 116 | 9·942308 | 28 | 7 |
| 54 | 36 | 9·684201 | 381 | 0·315799 | 9·741962 | 497 | 0·258038 | 0·057761 | 116 | 9·942239 | 24 | 6 |
| 55 | 40 | 9·684430 | 381 | 0·315570 | 9·742261 | 497 | 0·257739 | 0·057831 | 116 | 9·942169 | 20 | 5 |
| 56 | 44 | 9·684658 | 381 | 0·315342 | 9·742559 | 497 | 0·257441 | 0·057901 | 116 | 9 942099 | 16 | 4 |
| 57 | 48 | 9·684887 | 380 | 0·315113 | 9·742858 | 497 | 0·257142 | 0·057971 | 116 | 9·942029 | 12 | 3 |
| 58 | 52 | 9·685115 | 380 | 0·314885 | 9·743156 | 497 | 0·256844 | 0·058041 | 116 | 9·941959 | 8 | 2 |
| 59 | 56 | 9·685343 | 380 | 0·314657 | 9·743454 | 497 | 0·256546 | 0·058111 | 117 | 9·941889 | 4 | 1 |
| 60 | **56** | 9·685571 | | 0·314429 | 9·743752 | | 0·256248 | 0·058181 | | 9·941819 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

118° 61°=4h 4m 61°

## LOG. SINES, COSINES, &c.

29° 29°=1h 56m 150°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·685571 | 380 | 0·314429 | 9·743752 | 496 | 0·256248 | 0·058181 | 117 | 9·941819 | 4 | 60 |
| 1 | 4 | 9·685799 | 379 | 0·314201 | 9·744050 | 496 | 0·255950 | 0·058251 | 117 | 9·941749 | 56 | 59 |
| 2 | 8 | 9·686027 | 379 | 0·313973 | 9·744348 | 496 | 0·255652 | 0·058321 | 117 | 9·941679 | 52 | 58 |
| 3 | 12 | 9·686254 | 379 | 0·313746 | 9·744645 | 496 | 0·255355 | 0·058391 | 117 | 9·941609 | 48 | 57 |
| 4 | 16 | 9·686482 | 379 | 0·313518 | 9·744943 | 496 | 0·255057 | 0·058461 | 117 | 9·941539 | 44 | 56 |
| 5 | 20 | 9·686709 | 378 | 0·313291 | 9·745240 | 495 | 0·254760 | 0·058531 | 117 | 9·941469 | 40 | 55 |
| 6 | 24 | 9·686936 | 378 | 0·313064 | 9·745538 | 495 | 0·254462 | 0·058602 | 117 | 9·941398 | 36 | 54 |
| 7 | 28 | 9·687163 | 378 | 0·312837 | 9·745835 | 495 | 0·254165 | 0·058672 | 117 | 9·941328 | 32 | 53 |
| 8 | 32 | 9·687389 | 378 | 0·312611 | 9·746132 | 495 | 0·253868 | 0·058742 | 117 | 9·941258 | 28 | 52 |
| 9 | 36 | 9·687616 | 377 | 0·312384 | 9·746429 | 495 | 0·253571 | 0·058813 | 117 | 9·941187 | 24 | 51 |
| 10 | 40 | 9·687843 | 377 | 0·312157 | 9·746726 | 495 | 0·253274 | 0·058883 | 117 | 9·941117 | 20 | 50 |
| 11 | 44 | 9·688069 | 377 | 0·311931 | 9·747023 | 494 | 0·252977 | 0·058954 | 118 | 9·941046 | 16 | 49 |
| 12 | 48 | 9·688295 | 377 | 0·311705 | 9·747319 | 494 | 0·252681 | 0·059025 | 118 | 9·940975 | 12 | 48 |
| 13 | 52 | 9·688521 | 376 | 0·311479 | 9·747616 | 494 | 0·252384 | 0·059095 | 118 | 9·940905 | 8 | 47 |
| 14 | 56 | 9·688747 | 376 | 0·311253 | 9·747913 | 494 | 0·252087 | 0·059166 | 118 | 9·940834 | 4 | 46 |
| 15 | **57** | 9·688972 | 376 | 0·311028 | 9·748209 | 494 | 0·251791 | 0·059237 | 118 | 9·940763 | **3** | 45 |
| 16 | 4 | 9·689198 | 376 | 0·310802 | 9·748505 | 493 | 0·251495 | 0·059307 | 118 | 9·940693 | 56 | 44 |
| 17 | 8 | 9·689423 | 375 | 0·310577 | 9·748801 | 493 | 0·251199 | 0·059378 | 118 | 9·940622 | 52 | 43 |
| 18 | 12 | 9·689648 | 375 | 0·310352 | 9·749097 | 493 | 0·250903 | 0·059449 | 118 | 9·940551 | 48 | 42 |
| 19 | 16 | 9·689873 | 375 | 0·310127 | 9·749393 | 493 | 0·250607 | 0·059520 | 118 | 9·940480 | 44 | 41 |
| 20 | 20 | 9·690098 | 375 | 0·309902 | 9·749689 | 493 | 0·250311 | 0·059591 | 118 | 9·940409 | 40 | 40 |
| 21 | 24 | 9·690323 | 374 | 0·309677 | 9·749985 | 493 | 0·250015 | 0·059662 | 118 | 9·940338 | 36 | 39 |
| 22 | 28 | 9·690548 | 374 | 0·309452 | 9·750281 | 492 | 0·249719 | 0·059733 | 118 | 9·940267 | 32 | 38 |
| 23 | 32 | 9·690772 | 374 | 0·309228 | 9·750576 | 492 | 0·249424 | 0·059804 | 118 | 9·940196 | 28 | 37 |
| 24 | 36 | 9·690996 | 374 | 0·309004 | 9·750872 | 492 | 0·249128 | 0·059875 | 119 | 9·940125 | 24 | 36 |
| 25 | 40 | 9·691220 | 373 | 0·308780 | 9·751167 | 492 | 0·248833 | 0·059946 | 119 | 9·940054 | 20 | 35 |
| 26 | 44 | 9·691444 | 373 | 0·308556 | 9·751462 | 492 | 0·248538 | 0·060018 | 119 | 9·939982 | 16 | 34 |
| 27 | 48 | 9·691668 | 373 | 0·308332 | 9·751757 | 492 | 0·248243 | 0·060089 | 119 | 9·939911 | 12 | 33 |
| 28 | 52 | 9·691892 | 373 | 0·308108 | 9·752052 | 492 | 0·247948 | 0·060160 | 119 | 9·939840 | 8 | 32 |
| 29 | 56 | 9·692115 | 372 | 0·307885 | 9·752347 | 491 | 0·247653 | 0·060232 | 119 | 9·939768 | 4 | 31 |
| 30 | **58** | 9·692339 | 372 | 0·307661 | 9·752642 | 491 | 0·247358 | 0·060303 | 119 | 9·939697 | **2** | 30 |
| 31 | 4 | 9·692562 | 372 | 0·307438 | 9·752937 | 491 | 0·247063 | 0·060375 | 119 | 9·939625 | 56 | 29 |
| 32 | 8 | 9·692785 | 371 | 0·307215 | 9·753231 | 491 | 0·246769 | 0·060446 | 119 | 9·939554 | 52 | 28 |
| 33 | 12 | 9·693008 | 371 | 0·306992 | 9·753526 | 491 | 0·246474 | 0·060518 | 119 | 9·939482 | 48 | 27 |
| 34 | 16 | 9·693231 | 371 | 0·306769 | 9·753820 | 490 | 0·246180 | 0·060590 | 119 | 9·939410 | 44 | 26 |
| 35 | 20 | 9·693453 | 371 | 0·306547 | 9·754115 | 490 | 0·245885 | 0·060661 | 119 | 9·939339 | 40 | 25 |
| 36 | 24 | 9·693676 | 370 | 0·306324 | 9·754409 | 490 | 0·245591 | 0·060733 | 120 | 9·939267 | 36 | 24 |
| 37 | 28 | 9·693898 | 370 | 0·306102 | 9·754703 | 490 | 0·245297 | 0·060805 | 120 | 9·939195 | 32 | 23 |
| 38 | 32 | 9·694120 | 370 | 0·305880 | 9·754997 | 490 | 0·245003 | 0·060877 | 120 | 9·939123 | 28 | 22 |
| 39 | 36 | 9·694342 | 370 | 0·305658 | 9·755291 | 490 | 0·244709 | 0·060948 | 120 | 9·939052 | 24 | 21 |
| 40 | 40 | 9·694564 | 369 | 0·305436 | 9·755585 | 489 | 0·244415 | 0·061020 | 120 | 9·938980 | 20 | 20 |
| 41 | 44 | 9·694786 | 369 | 0·305214 | 9·755878 | 489 | 0·244122 | 0·061092 | 120 | 9·938908 | 16 | 19 |
| 42 | 48 | 9·695007 | 369 | 0·304993 | 9·756172 | 489 | 0·243828 | 0·061164 | 120 | 9·938836 | 12 | 18 |
| 43 | 52 | 9·695229 | 369 | 0·304771 | 9·756465 | 489 | 0·243535 | 0·061237 | 120 | 9·938763 | 8 | 17 |
| 44 | 56 | 9·695450 | 368 | 0·304550 | 9·756759 | 489 | 0·243241 | 0·061309 | 120 | 9·938691 | 4 | 16 |
| 45 | **59** | 9·695671 | 368 | 0·304329 | 9·757052 | 489 | 0·242948 | 0·061381 | 120 | 9·938619 | **1** | 15 |
| 46 | 4 | 9·695892 | 368 | 0·304108 | 9·757345 | 488 | 0·242655 | 0·061453 | 120 | 9·938547 | 56 | 14 |
| 47 | 8 | 9·696113 | 368 | 0·303887 | 9·757638 | 488 | 0·242362 | 0·061525 | 120 | 9·938475 | 52 | 13 |
| 48 | 12 | 9·696334 | 367 | 0·303666 | 9·757931 | 488 | 0·242069 | 0·061598 | 121 | 9·938402 | 48 | 12 |
| 49 | 16 | 9·696554 | 367 | 0·303446 | 9·758224 | 488 | 0·241776 | 0·061670 | 121 | 9·938330 | 44 | 11 |
| 50 | 20 | 9·696775 | 367 | 0·303225 | 9·758517 | 488 | 0·241483 | 0·061742 | 121 | 9·938258 | 40 | 10 |
| 51 | 24 | 9·696995 | 367 | 0·303005 | 9·758810 | 488 | 0·241190 | 0·061815 | 121 | 9·938185 | 36 | 9 |
| 52 | 28 | 9·697215 | 366 | 0·302785 | 9·759102 | 487 | 0·240898 | 0·061887 | 121 | 9·938113 | 32 | 8 |
| 53 | 32 | 9·697435 | 366 | 0·302565 | 9·759395 | 487 | 0·240605 | 0·061960 | 121 | 9·938040 | 28 | 7 |
| 54 | 36 | 9·697654 | 366 | 0·302346 | 9·759687 | 487 | 0·240313 | 0·062033 | 121 | 9·937967 | 24 | 6 |
| 55 | 40 | 9·697874 | 366 | 0·302126 | 9·759979 | 487 | 0·240021 | 0·062105 | 121 | 9·937895 | 20 | 5 |
| 56 | 44 | 9·698094 | 366 | 0·301906 | 9·760272 | 487 | 0·239728 | 0·062178 | 121 | 9·937822 | 16 | 4 |
| 57 | 48 | 9·698313 | 365 | 0·301687 | 9·760564 | 487 | 0·239436 | 0·062251 | 121 | 9·937749 | 12 | 3 |
| 58 | 52 | 9·698532 | 365 | 0·301468 | 9·760856 | 486 | 0·239144 | 0·062324 | 121 | 9·937676 | 8 | 2 |
| 59 | 56 | 9·698751 | 365 | 0·301249 | 9·761148 | 486 | 0·238852 | 0·062396 | 121 | 9·937604 | 4 | 1 |
| 60 | **60** | 9·698970 | | 0·301030 | 9·761439 | | 0·238561 | 0·062469 | | 9·937531 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

119° 60°=4h 0m 60°

## LOG. SINES, COSINES, &c.

30° | 30°=2h 0m | 149°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·698970 | 364 | 0·301030 | 9·761439 | 486 | 0·238561 | 0·062469 | 121 | 9·937531 | **60** | 60 |
| 1 | 4 | 9·699189 | 364 | 0·300811 | 9·761731 | 486 | 0·238269 | 0·062542 | 122 | 9·937458 | 56 | 59 |
| 2 | 8 | 9·699407 | 364 | 0·300593 | 9·762023 | 486 | 0·237977 | 0·062615 | 122 | 9·937385 | 52 | 58 |
| 3 | 12 | 9·699626 | 364 | 0·300374 | 9·762314 | 486 | 0·237686 | 0·062688 | 122 | 9·937312 | 48 | 57 |
| 4 | 16 | 9·699844 | 363 | 0·300156 | 9·762606 | 485 | 0·237394 | 0·062762 | 122 | 9·937238 | 44 | 56 |
| 5 | 20 | 9·700062 | 363 | 0·299938 | 9·762897 | 485 | 0·237103 | 0·062835 | 122 | 9·937165 | 40 | 55 |
| 6 | 24 | 9·700280 | 363 | 0·299720 | 9·763188 | 485 | 0·236812 | 0·062908 | 122 | 9·937092 | 36 | 54 |
| 7 | 28 | 9·700498 | 363 | 0·299502 | 9·763479 | 485 | 0·236521 | 0·062981 | 122 | 9·937019 | 32 | 53 |
| 8 | 32 | 9·700716 | 363 | 0·299284 | 9·763770 | 485 | 0·236230 | 0·063054 | 122 | 9·936946 | 28 | 52 |
| 9 | 36 | 9·700933 | 362 | 0·299067 | 9·764061 | 485 | 0·235939 | 0·063128 | 122 | 9·936872 | 24 | 51 |
| 10 | 40 | 9·701151 | 362 | 0·298849 | 9·764352 | 484 | 0·235648 | 0·063201 | 122 | 9·936799 | 20 | 50 |
| 11 | 44 | 9·701368 | 362 | 0·298632 | 9·764643 | 484 | 0·235357 | 0·063275 | 122 | 9·936725 | 16 | 49 |
| 12 | 48 | 9·701585 | 362 | 0·298415 | 9·764933 | 484 | 0·235067 | 0·063348 | 123 | 9·936652 | 12 | 48 |
| 13 | 52 | 9·701802 | 361 | 0·298198 | 9·765224 | 484 | 0·234776 | 0·063422 | 123 | 9·936578 | 8 | 47 |
| 14 | 56 | 9·702019 | 361 | 0·297981 | 9·765514 | 484 | 0·234486 | 0·063495 | 123 | 9·936505 | 4 | 46 |
| 15 | **1** | 9·702236 | 361 | 0·297764 | 9·765805 | 484 | 0·234195 | 0·063569 | 123 | 9·936431 | **59** | 45 |
| 16 | 4 | 9·702452 | 361 | 0·297548 | 9·766095 | 484 | 0·233905 | 0·063643 | 123 | 9·936357 | 56 | 44 |
| 17 | 8 | 9·702669 | 360 | 0·297331 | 9·766385 | 483 | 0·233615 | 0·063716 | 123 | 9·936284 | 52 | 43 |
| 18 | 12 | 9·702885 | 360 | 0·297115 | 9·766675 | 483 | 0·233325 | 0·063790 | 123 | 9·936210 | 48 | 42 |
| 19 | 16 | 9·703101 | 360 | 0·296899 | 9·766965 | 483 | 0·233035 | 0·063864 | 123 | 9·936136 | 44 | 41 |
| 20 | 20 | 9·703317 | 360 | 0·296683 | 9·767255 | 483 | 0·232745 | 0·063938 | 123 | 9·936062 | 40 | 40 |
| 21 | 24 | 9·703533 | 359 | 0·296467 | 9·767545 | 483 | 0·232455 | 0·064012 | 123 | 9·935988 | 36 | 39 |
| 22 | 28 | 9·703749 | 359 | 0·296251 | 9·767834 | 483 | 0·232166 | 0·064086 | 123 | 9·935914 | 32 | 38 |
| 23 | 32 | 9·703964 | 359 | 0·296036 | 9·768124 | 482 | 0·231876 | 0·064160 | 123 | 9·935840 | 28 | 37 |
| 24 | 36 | 9·704179 | 359 | 0·295821 | 9·768413 | 482 | 0·231587 | 0·064234 | 124 | 9·935766 | 24 | 36 |
| 25 | 40 | 9·704395 | 359 | 0·295605 | 9·768703 | 482 | 0·231297 | 0·064308 | 124 | 9·935692 | 20 | 35 |
| 26 | 44 | 9·704610 | 358 | 0·295390 | 9·768992 | 482 | 0·231008 | 0·064382 | 124 | 9·935618 | 16 | 34 |
| 27 | 48 | 9·704825 | 358 | 0·295175 | 9·769281 | 482 | 0·230719 | 0·064457 | 124 | 9·935543 | 12 | 33 |
| 28 | 52 | 9·705040 | 358 | 0·294960 | 9·769570 | 482 | 0·230430 | 0·064531 | 124 | 9·935469 | 8 | 32 |
| 29 | 56 | 9·705254 | 358 | 0·294746 | 9·769860 | 481 | 0·230140 | 0·064605 | 124 | 9·935395 | 4 | 31 |
| 30 | **2** | 9·705469 | 357 | 0·294531 | 9·770148 | 481 | 0·229852 | 0·064680 | 124 | 9·935320 | **58** | 30 |
| 31 | 4 | 9·705683 | 357 | 0·294317 | 9·770437 | 481 | 0·229563 | 0·064754 | 124 | 9·935246 | 56 | 29 |
| 32 | 8 | 9·705898 | 357 | 0·294102 | 9·770726 | 481 | 0·229274 | 0·064829 | 124 | 9·935171 | 52 | 28 |
| 33 | 12 | 9·706112 | 357 | 0·293888 | 9·771015 | 481 | 0·228985 | 0·064903 | 124 | 9·935097 | 48 | 27 |
| 34 | 16 | 9·706326 | 356 | 0·293674 | 9·771303 | 481 | 0·228697 | 0·064978 | 124 | 9·935022 | 44 | 26 |
| 35 | 20 | 9·706539 | 356 | 0·293461 | 9·771592 | 481 | 0·228408 | 0·065052 | 124 | 9·934948 | 40 | 25 |
| 36 | 24 | 9·706753 | 356 | 0·293247 | 9·771880 | 480 | 0·228120 | 0·065127 | 124 | 9·934873 | 36 | 24 |
| 37 | 28 | 9·706967 | 356 | 0·293033 | 9·772168 | 480 | 0·227832 | 0·065202 | 125 | 9·934798 | 32 | 23 |
| 38 | 32 | 9·707180 | 355 | 0·292820 | 9·772457 | 480 | 0·227543 | 0·065277 | 125 | 9·934723 | 28 | 22 |
| 39 | 36 | 9·707393 | 355 | 0·292607 | 9·772745 | 480 | 0·227255 | 0·065351 | 125 | 9·934649 | 24 | 21 |
| 40 | 40 | 9·707606 | 355 | 0·292394 | 9·773033 | 480 | 0·226967 | 0·065426 | 125 | 9·934574 | 20 | 20 |
| 41 | 44 | 9·707819 | 355 | 0·292181 | 9·773321 | 480 | 0·226679 | 0·065501 | 125 | 9·934499 | 16 | 19 |
| 42 | 48 | 9·708032 | 354 | 0·291968 | 9·773608 | 479 | 0·226392 | 0·065576 | 125 | 9·934424 | 12 | 18 |
| 43 | 52 | 9·708245 | 354 | 0·291755 | 9·773896 | 479 | 0·226104 | 0·065651 | 125 | 9·934349 | 8 | 17 |
| 44 | 56 | 9·708458 | 354 | 0·291542 | 9·774184 | 479 | 0·225816 | 0·065726 | 125 | 9·934274 | 4 | 16 |
| 45 | **3** | 9·708670 | 354 | 0·291330 | 9·774471 | 479 | 0·225529 | 0·065801 | 125 | 9·934199 | **57** | 15 |
| 46 | 4 | 9·708882 | 353 | 0·291118 | 9·774759 | 479 | 0·225241 | 0·065877 | 125 | 9·934123 | 56 | 14 |
| 47 | 8 | 9·709094 | 353 | 0·290906 | 9·775046 | 479 | 0·224954 | 0·065952 | 125 | 9·934048 | 52 | 13 |
| 48 | 12 | 9·709306 | 353 | 0·290694 | 9·775333 | 479 | 0·224667 | 0·066027 | 125 | 9·933973 | 48 | 12 |
| 49 | 16 | 9·709518 | 353 | 0·290482 | 9·775621 | 478 | 0·224379 | 0·066102 | 126 | 9·933898 | 44 | 11 |
| 50 | 20 | 9·709730 | 353 | 0·290270 | 9·775908 | 478 | 0·224092 | 0·066178 | 126 | 9·933822 | 40 | 10 |
| 51 | 24 | 9·709941 | 352 | 0·290059 | 9·776195 | 478 | 0·223805 | 0·066253 | 126 | 9·933747 | 36 | 9 |
| 52 | 28 | 9·710153 | 352 | 0·289847 | 9·776482 | 478 | 0·223518 | 0·066329 | 126 | 9·933671 | 32 | 8 |
| 53 | 32 | 9·710364 | 352 | 0·289636 | 9·776768 | 478 | 0·223232 | 0·066404 | 126 | 9·933596 | 28 | 7 |
| 54 | 36 | 9·710575 | 352 | 0·289425 | 9·777055 | 478 | 0·222945 | 0·066480 | 126 | 9·933520 | 24 | 6 |
| 55 | 40 | 9·710786 | 351 | 0·289214 | 9·777342 | 478 | 0·222658 | 0·066555 | 126 | 9·933445 | 20 | 5 |
| 56 | 44 | 9·710997 | 351 | 0·289003 | 9·777628 | 477 | 0·222372 | 0·066631 | 126 | 9·933369 | 16 | 4 |
| 57 | 48 | 9·711208 | 351 | 0·288792 | 9·777915 | 477 | 0·222085 | 0·066707 | 126 | 9·933293 | 12 | 3 |
| 58 | 52 | 9·711419 | 351 | 0·288581 | 9·778201 | 477 | 0·221799 | 0·066783 | 126 | 9·933217 | 8 | 2 |
| 59 | 56 | 9·711629 | 350 | 0·288371 | 9·778488 | 477 | 0·221512 | 0·066859 | 126 | 9·933141 | 4 | 1 |
| 60 | **4** | 9·711839 | | 0·288161 | 9·778774 | | 0·221226 | 0·066934 | | 9·933066 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

120° | 59°=3h 56m | 59°

## LOG. SINES, COSINES, &c.

31° 31°=2h 4m 148°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·711839 | 350 | 0·288161 | 9·778774 | 477 | 0·221226 | 0·066934 | 126 | 9·933066 | **56** | 60 |
| 1 | 4 | 9·712050 | 350 | 0·287950 | 9·779060 | 477 | 0·220940 | 0·067010 | 127 | 9·932990 | 56 | 59 |
| 2 | 8 | 9·712260 | 350 | 0·287740 | 9·779346 | 476 | 0·220654 | 0·067086 | 127 | 9·932914 | 52 | 58 |
| 3 | 12 | 9·712469 | 349 | 0·287531 | 9·779632 | 476 | 0·220368 | 0·067162 | 127 | 9·932838 | 48 | 57 |
| 4 | 16 | 9·712679 | 349 | 0·287321 | 9·779918 | 476 | 0·220082 | 0·067238 | 127 | 9·932762 | 44 | 56 |
| 5 | 20 | 9·712889 | 349 | 0·287111 | 9·780203 | 476 | 0·219797 | 0·067315 | 127 | 9·932685 | 40 | 55 |
| 6 | 24 | 9·713098 | 349 | 0·286902 | 9·780489 | 476 | 0·219511 | 0·067391 | 127 | 9·932609 | 36 | 54 |
| 7 | 28 | 9·713308 | 349 | 0·286692 | 9·780775 | 476 | 0·219225 | 0·067467 | 127 | 9·932533 | 32 | 53 |
| 8 | 32 | 9·713517 | 349 | 0·286483 | 9·781060 | 476 | 0·218940 | 0·067543 | 127 | 9·932457 | 28 | 52 |
| 9 | 36 | 9·713726 | 348 | 0·286274 | 9·781346 | 476 | 0·218654 | 0·067620 | 127 | 9·932380 | 24 | 51 |
| 10 | 40 | 9·713935 | 348 | 0·286065 | 9·781631 | 475 | 0·218369 | 0·067696 | 127 | 9·932304 | 20 | 50 |
| 11 | 44 | 9·714144 | 348 | 0·285856 | 9·781916 | 475 | 0·218084 | 0·067772 | 127 | 9·932228 | 16 | 49 |
| 12 | 48 | 9·714352 | 348 | 0·285648 | 9·782201 | 475 | 0·217799 | 0·067849 | 127 | 9·932151 | 12 | 48 |
| 13 | 52 | 9·714561 | 347 | 0·285439 | 9·782486 | 475 | 0·217514 | 0·067925 | 128 | 9·932075 | 8 | 47 |
| 14 | 56 | 9·714769 | 347 | 0·285231 | 9·782771 | 475 | 0·217229 | 0·068002 | 128 | 9·931998 | 4 | 46 |
| 15 | **5** | 9·714978 | 347 | 0·285022 | 9·783056 | 475 | 0·216944 | 0·068079 | 128 | 9·931921 | **55** | 45 |
| 16 | 4 | 9·715186 | 347 | 0·284814 | 9·783341 | 475 | 0·216659 | 0·068155 | 128 | 9·931845 | 56 | 44 |
| 17 | 8 | 9·715394 | 346 | 0·284606 | 9·783626 | 474 | 0·216374 | 0·068232 | 128 | 9·931768 | 52 | 43 |
| 18 | 12 | 9·715602 | 346 | 0·284398 | 9·783910 | 474 | 0·216090 | 0·068309 | 128 | 9·931691 | 48 | 42 |
| 19 | 16 | 9·715809 | 346 | 0·284191 | 9·784195 | 474 | 0·215805 | 0·068386 | 128 | 9·931614 | 44 | 41 |
| 20 | 20 | 9·716017 | 346 | 0·283983 | 9·784479 | 474 | 0·215521 | 0·068463 | 128 | 9·931537 | 40 | 40 |
| 21 | 24 | 9·716224 | 345 | 0·283776 | 9·784764 | 474 | 0·215236 | 0·068540 | 128 | 9·931460 | 36 | 39 |
| 22 | 28 | 9·716432 | 345 | 0·283568 | 9·785048 | 474 | 0·214952 | 0·068617 | 128 | 9·931383 | 32 | 38 |
| 23 | 32 | 9·716639 | 345 | 0·283361 | 9·785332 | 473 | 0·214668 | 0·068694 | 128 | 9·931306 | 28 | 37 |
| 24 | 36 | 9·716846 | 345 | 0·283154 | 9·785616 | 473 | 0·214384 | 0·068771 | 129 | 9·931229 | 24 | 36 |
| 25 | 40 | 9·717053 | 345 | 0·282947 | 9·785900 | 473 | 0·214100 | 0·068848 | 129 | 9·931152 | 20 | 35 |
| 26 | 44 | 9·717259 | 344 | 0·282741 | 9·786184 | 473 | 0·213816 | 0·068925 | 129 | 9·931075 | 16 | 34 |
| 27 | 48 | 9·717466 | 344 | 0·282534 | 9·786468 | 473 | 0·213532 | 0·069002 | 129 | 9·930998 | 12 | 33 |
| 28 | 52 | 9·717673 | 344 | 0·282327 | 9·786752 | 473 | 0·213248 | 0·069079 | 129 | 9·930921 | 8 | 32 |
| 29 | 56 | 9·717879 | 344 | 0·282121 | 9·787036 | 473 | 0·212964 | 0·069157 | 129 | 9·930843 | 4 | 31 |
| 30 | **6** | 9·718085 | 343 | 0·281915 | 9·787319 | 472 | 0·212681 | 0·069234 | 129 | 9·930766 | **54** | 30 |
| 31 | 4 | 9·718291 | 343 | 0·281709 | 9·787603 | 472 | 0·212397 | 0·069312 | 129 | 9·930688 | 56 | 29 |
| 32 | 8 | 9·718497 | 343 | 0·281503 | 9·787886 | 472 | 0·212114 | 0·069389 | 129 | 9·930611 | 52 | 28 |
| 33 | 12 | 9·718703 | 343 | 0·281297 | 9·788170 | 472 | 0·211830 | 0·069467 | 129 | 9·930533 | 48 | 27 |
| 34 | 16 | 9·718909 | 343 | 0·281091 | 9·788453 | 472 | 0·211547 | 0·069544 | 129 | 9·930456 | 44 | 26 |
| 35 | 20 | 9·719114 | 342 | 0·280886 | 9·788736 | 472 | 0·211264 | 0·069622 | 129 | 9·930378 | 40 | 25 |
| 36 | 24 | 9·719320 | 342 | 0·280680 | 9·789019 | 472 | 0·210981 | 0·069700 | 130 | 9·930300 | 36 | 24 |
| 37 | 28 | 9·719525 | 342 | 0·280475 | 9·789302 | 471 | 0·210698 | 0·069777 | 130 | 9·930223 | 32 | 23 |
| 38 | 32 | 9·719730 | 342 | 0·280270 | 9·789585 | 471 | 0·210415 | 0·069855 | 130 | 9·930145 | 28 | 22 |
| 39 | 36 | 9·719935 | 341 | 0·280065 | 9·789868 | 471 | 0·210132 | 0·069933 | 130 | 9·930067 | 24 | 21 |
| 40 | 40 | 9·720140 | 341 | 0·279860 | 9·790151 | 471 | 0·209849 | 0·070011 | 130 | 9·929989 | 20 | 20 |
| 41 | 44 | 9·720345 | 341 | 0·279655 | 9·790434 | 471 | 0·209566 | 0·070089 | 130 | 9·929911 | 16 | 19 |
| 42 | 48 | 9·720549 | 341 | 0·279451 | 9·790716 | 471 | 0·209284 | 0·070167 | 130 | 9·929833 | 12 | 18 |
| 43 | 52 | 9·720754 | 340 | 0·279246 | 9·790999 | 471 | 0·209001 | 0·070245 | 130 | 9·929755 | 8 | 17 |
| 44 | 56 | 9·720958 | 340 | 0·279042 | 9·791281 | 471 | 0·208719 | 0·070323 | 130 | 9·929677 | 4 | 16 |
| 45 | **7** | 9·721162 | 340 | 0·278838 | 9·791563 | 470 | 0·208437 | 0·070401 | 130 | 9·929599 | **53** | 15 |
| 46 | 4 | 9·721366 | 340 | 0·278634 | 9·791846 | 470 | 0·208154 | 0·070479 | 130 | 9·929521 | 56 | 14 |
| 47 | 8 | 9·721570 | 340 | 0·278430 | 9·792128 | 470 | 0·207872 | 0·070558 | 130 | 9·929442 | 52 | 13 |
| 48 | 12 | 9·721774 | 339 | 0·278226 | 9·792410 | 470 | 0·207590 | 0·070636 | 131 | 9·929364 | 48 | 12 |
| 49 | 16 | 9·721978 | 339 | 0·278022 | 9·792692 | 470 | 0·207308 | 0·070714 | 131 | 9·929286 | 44 | 11 |
| 50 | 20 | 9·722181 | 339 | 0·277819 | 9·792974 | 470 | 0·207026 | 0·070793 | 131 | 9·929207 | 40 | 10 |
| 51 | 24 | 9·722385 | 339 | 0·277615 | 9·793256 | 470 | 0·206744 | 0·070871 | 131 | 9·929129 | 36 | 9 |
| 52 | 28 | 9·722588 | 339 | 0·277412 | 9·793538 | 469 | 0·206462 | 0·070950 | 131 | 9·929050 | 32 | 8 |
| 53 | 32 | 9·722791 | 338 | 0·277209 | 9·793819 | 469 | 0·206181 | 0·071028 | 131 | 9·928972 | 28 | 7 |
| 54 | 36 | 9·722994 | 338 | 0·277006 | 9·794101 | 469 | 0·205899 | 0·071107 | 131 | 9·928893 | 24 | 6 |
| 55 | 40 | 9·723197 | 338 | 0·276803 | 9·794383 | 469 | 0·205617 | 0·071185 | 131 | 9·928815 | 20 | 5 |
| 56 | 44 | 9·723400 | 338 | 0·276600 | 9·794664 | 469 | 0·205336 | 0·071264 | 131 | 9·928736 | 16 | 4 |
| 57 | 48 | 9·723603 | 337 | 0·276397 | 9·794946 | 469 | 0·205054 | 0·071343 | 131 | 9·928657 | 12 | 3 |
| 58 | 52 | 9·723805 | 337 | 0·276195 | 9·795227 | 469 | 0·204773 | 0·071422 | 131 | 9·928578 | 8 | 2 |
| 59 | 56 | 9·724007 | 337 | 0·275993 | 9·795508 | 468 | 0·204492 | 0·071501 | 131 | 9·928499 | 4 | 1 |
| 60 | **8** | 9·724210 | | 0·275790 | 9·795789 | | 0·204211 | 0·071580 | | 9·928420 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

121° 58°=3h 52m 58°

## LOG. SINES, COSINES, &c.

32° 32°=2h 8m 147°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·724210 | 337 | 0·275790 | 9·795789 | 468 | 0·204211 | 0·071580 | 132 | 9·928420 | **52** | 60 |
| 1 | 4 | 9·724412 | 337 | 0·275588 | 9·796070 | 468 | 0·203930 | 0 071658 | 132 | 9·928342 | 56 | 59 |
| 2 | 8 | 9·724614 | 336 | 0·275386 | 9·796351 | 468 | 0·203649 | 0·071737 | 132 | 9·928263 | 52 | 58 |
| 3 | 12 | 9·724816 | 336 | 0·275184 | 9 796632 | 468 | 0·203368 | 0·071817 | 132 | 9 928183 | 48 | 57 |
| 4 | 16 | 9·725017 | 336 | 0·274983 | 9 796913 | 468 | 0·203087 | 0·071896 | 132 | 9 928104 | 44 | 56 |
| 5 | 20 | 9·725219 | 336 | 0·274781 | 9 797194 | 468 | 0·202806 | 0·071975 | 132 | 9 928025 | 40 | 55 |
| 6 | 24 | 9·725420 | 335 | 0·274580 | 9·797474 | 468 | 0·202526 | 0·072054 | 132 | 9·927946 | 36 | 54 |
| 7 | 28 | 9 725622 | 335 | 0·274378 | 9 797755 | 468 | 0·202245 | 0·072133 | 132 | 9 927867 | 32 | 53 |
| 8 | 32 | 9·725823 | 335 | 0·274177 | 9 798036 | 467 | 0·201964 | 0·072213 | 132 | 9 927787 | 28 | 52 |
| 9 | 36 | 9·726024 | 335 | 0·273976 | 9 798316 | 467 | 0·201684 | 0·072292 | 132 | 9 927708 | 24 | 51 |
| 10 | 40 | 9·726225 | 335 | 0·273775 | 9 798596 | 467 | 0·201404 | 0·072371 | 132 | 9 927629 | 20 | 50 |
| 11 | 44 | 9·726426 | 334 | 0·273574 | 9·798877 | 467 | 0 201123 | 0·072451 | 132 | 9·927549 | 16 | 49 |
| 12 | 48 | 9·726626 | 334 | 0·273374 | 9 799157 | 467 | 0·200843 | 0·072530 | 133 | 9·927470 | 12 | 48 |
| 13 | 52 | 9·726827 | 334 | 0 273173 | 9·799437 | 467 | 0·200563 | 0·072610 | 133 | 9·927390 | 8 | 47 |
| 14 | 56 | 9·727027 | 334 | 0·272973 | 9·799717 | 467 | 0·200283 | 0·072690 | 133 | 9·927310 | 4 | 46 |
| 15 | **9** | 9·727228 | 334 | 0·272772 | 9 799997 | 466 | 0·200003 | 0·072769 | 133 | 9·927231 | **51** | 45 |
| 16 | 4 | 9·727428 | 333 | 0·272572 | 9 800277 | 466 | 0·199723 | 0·072849 | 133 | 9 927151 | 56 | 44 |
| 17 | 8 | 9·727628 | 333 | 0 272372 | 9 800557 | 466 | 0·199443 | 0 072929 | 133 | 9 927071 | 52 | 43 |
| 18 | 12 | 9·727828 | 333 | 0 272172 | 9·800836 | 466 | 0·199164 | 0 073009 | 133 | 9 926991 | 48 | 42 |
| 19 | 16 | 9·728027 | 333 | 0 271972 | 9 801116 | 466 | 0·198884 | 0 073089 | 133 | 9 926911 | 44 | 41 |
| 20 | 20 | 9·728227 | 333 | 0 271773 | 9 801396 | 466 | 0 198604 | 0 073169 | 133 | 9 926831 | 40 | 40 |
| 21 | 24 | 9·728427 | 332 | 0 271573 | 9 801675 | 466 | 0 198325 | 0·073249 | 133 | 9·926751 | 36 | 39 |
| 22 | 28 | 9·728626 | 332 | 0 271374 | 9 801955 | 466 | 0 198045 | 0·073329 | 133 | 9 926671 | 32 | 38 |
| 23 | 32 | 9·728825 | 332 | 0 271175 | 9·802234 | 465 | 0 197766 | 0·073409 | 133 | 9 926591 | 28 | 37 |
| 24 | 36 | 9·729024 | 332 | 0·270976 | 9·802513 | 465 | 0 197487 | 0·073489 | 134 | 9·926511 | 24 | **36** |
| 25 | 40 | 9·729223 | 331 | 0 270777 | 9 802792 | 465 | 0·197208 | 0·073569 | 134 | 9·926431 | 20 | 35 |
| 26 | 44 | 9·729422 | 331 | 0·270578 | 9 803072 | 465 | 0 196928 | 0 073649 | 134 | 9 926351 | 16 | 34 |
| 27 | 48 | 9·729621 | 331 | 0·270379 | 9 803351 | 465 | 0·196649 | 0 073730 | 134 | 9·926270 | 12 | 33 |
| 28 | 52 | 9·729820 | 331 | 0 270180 | 9 803630 | 465 | 0 196370 | 0 073810 | 134 | 9·926190 | 8 | 32 |
| 29 | 56 | 9·730018 | 330 | 0 269982 | 9·803909 | 465 | 0·196091 | 0·073890 | 134 | 9·926110 | 4 | 31 |
| 30 | **10** | 9·730217 | 330 | 0 269783 | 9·804187 | 465 | 0 195813 | 0 073971 | 134 | 9 926029 | **50** | 30 |
| 31 | 4 | 9·730415 | 330 | 0 269585 | 9 804466 | 464 | 0 195534 | 0·074051 | 134 | 9·925949 | 56 | 29 |
| 32 | 8 | 9·730613 | 330 | 0·269387 | 9 804745 | 464 | 0 195255 | 0 074132 | 134 | 9·925868 | 52 | 28 |
| 33 | 12 | 9·730811 | 330 | 0 269189 | 9 805023 | 464 | 0·194977 | 0·074212 | 134 | 9 925788 | 48 | 27 |
| 34 | 16 | 9·731009 | 329 | 0·268991 | 9 805302 | 464 | 0 194698 | 0·074293 | 134 | 9 925707 | 44 | 26 |
| 35 | 20 | 9·731206 | 329 | 0 268794 | 9 805580 | 464 | 0·194420 | 0 074374 | 134 | 9 925626 | 40 | 25 |
| 36 | 24 | 9·731404 | 329 | 0 268596 | 9 805859 | 464 | 0 194141 | 0 074455 | 135 | 9 925545 | 36 | 24 |
| 37 | 28 | 9·731602 | 329 | 0 268398 | 9·806137 | 464 | 0 193863 | 0·074535 | 135 | 9 925465 | 32 | 23 |
| 38 | 32 | 9·731799 | 329 | 0·268201 | 9 806415 | 463 | 0 193585 | 0·074616 | 135 | 9·925384 | 28 | 22 |
| 39 | 36 | 9·731996 | 328 | 0·268004 | 9 806693 | 463 | 0 193307 | 0·074697 | 135 | 9·925303 | 24 | 21 |
| 40 | 40 | 9·732193 | 328 | 0·267807 | 9 806971 | 463 | 0 193029 | 0 074778 | 135 | 9 925222 | 20 | 20 |
| 41 | 44 | 9·732390 | 328 | 0·267610 | 9 807249 | 463 | 0 192751 | 0 074859 | 135 | 9·925141 | 16 | 19 |
| 42 | 48 | 9·732587 | 328 | 0·267413 | 9 807527 | 463 | 0 192473 | 0·074940 | 135 | 9 925060 | 12 | 18 |
| 43 | 52 | 9·732784 | 328 | 0·267216 | 9·807805 | 463 | 0 192195 | 0·075021 | 135 | 9 924979 | 8 | 17 |
| 44 | 56 | 9·732980 | 327 | 0·267020 | 9 808083 | 463 | 0 191917 | 0·075103 | 135 | 9 924897 | 4 | 16 |
| 45 | **11** | 9·733177 | 327 | 0·266823 | 9 808361 | 463 | 0·191639 | 0·075184 | 135 | 9 924816 | **49** | 15 |
| 46 | 4 | 9·733373 | 327 | 0·266627 | 9·808638 | 462 | 0·191362 | 0·075265 | 136 | 9 924735 | 56 | 14 |
| 47 | 8 | 9·733569 | 327 | 0·266431 | 9 808916 | 462 | 0·191084 | 0·075346 | 136 | 9 924654 | 52 | 13 |
| 48 | 12 | 9·733765 | 327 | 0·266235 | 9·809193 | 462 | 0·190807 | 0·075428 | 136 | 9 924572 | 48 | 12 |
| 49 | 16 | 9·733961 | 326 | 0·266039 | 9 809471 | 462 | 0·190529 | 0·075509 | 136 | 9 924491 | 44 | 11 |
| 50 | 20 | 9·734157 | 326 | 0·265843 | 9 809748 | 462 | 0·190252 | 0·075591 | 136 | 9 924409 | 40 | 10 |
| 51 | 24 | 9·734353 | 326 | 0·265647 | 9 810025 | 462 | 0·189975 | 0·075672 | 136 | 9·924328 | 36 | 9 |
| 52 | 28 | 9·734549 | 326 | 0·265451 | 9 810302 | 462 | 0·189698 | 0·075754 | 136 | 9 924246 | 32 | 8 |
| 53 | 32 | 9·734744 | 325 | 0·265256 | 9·810580 | 462 | 0·189420 | 0·075836 | 136 | 9 924164 | 28 | 7 |
| 54 | 36 | 9·734939 | 325 | 0·265061 | 9 810857 | 462 | 0·189143 | 0·075917 | 136 | 9 924083 | 24 | 6 |
| 55 | 40 | 9·735135 | 325 | 0·264865 | 9·811134 | 461 | 0·188866 | 0·075999 | 136 | 9 924001 | 20 | 5 |
| 56 | 44 | 9·735330 | 325 | 0·264670 | 9 811410 | 461 | 0·188590 | 0·076081 | 136 | 9 923919 | 16 | 4 |
| 57 | 48 | 9·735525 | 325 | 0·264475 | 9 811687 | 461 | 0·188313 | 0·076163 | 136 | 9·923837 | 12 | 3 |
| 58 | 52 | 9·735719 | 324 | 0·264281 | 9·811964 | 461 | 0·188036 | 0·076245 | 137 | 9·923755 | 8 | 2 |
| 59 | 56 | 9·735914 | 324 | 0·264086 | 9 812241 | 461 | 0·187759 | 0·076327 | 137 | 9·923673 | 4 | 1 |
| 60 | **12** | 9·736109 | | 0·263891 | 9·812517 | | 0·187483 | 0·076409 | | 9·923591 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

122° 57°=3h 48m 57°

## LOG. SINES, COSINES, &c.

33° 33°=2h 12m 146°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·736109 | 324 | 0·263891 | 9·812517 | 461 | 0·187483 | 0·076409 | 137 | 9·923591 | 48 | 60 |
| 1 | 4 | 9·736303 | 324 | 0·263697 | 9·812794 | 461 | 0·187206 | 0·076491 | 137 | 9·923509 | 56 | 59 |
| 2 | 8 | 9·736498 | 324 | 0·263502 | 9·813070 | 461 | 0·186930 | 0·076573 | 137 | 9·923427 | 52 | 58 |
| 3 | 12 | 9·736692 | 323 | 0·263308 | 9·813347 | 460 | 0·186653 | 0·076655 | 137 | 9·923345 | 48 | 57 |
| 4 | 16 | 9·736886 | 323 | 0·263114 | 9·813623 | 460 | 0·186377 | 0·076737 | 137 | 9·923263 | 44 | 56 |
| 5 | 20 | 9·737080 | 323 | 0·262920 | 9·813899 | 460 | 0·186101 | 0·076819 | 137 | 9·923181 | 40 | 55 |
| 6 | 24 | 9·737274 | 323 | 0·262726 | 9·814176 | 460 | 0·185824 | 0·076902 | 137 | 9·923098 | 36 | 54 |
| 7 | 28 | 9·737467 | 323 | 0·262533 | 9·814452 | 460 | 0·185548 | 0·076984 | 137 | 9·923016 | 32 | 53 |
| 8 | 32 | 9·737661 | 322 | 0·262339 | 9·814728 | 460 | 0·185272 | 0·077067 | 137 | 9·922933 | 28 | 52 |
| 9 | 36 | 9·737855 | 322 | 0·262145 | 9·815004 | 460 | 0·184996 | 0·077149 | 137 | 9·922851 | 24 | 51 |
| 10 | 40 | 9·738048 | 322 | 0·261952 | 9·815280 | 460 | 0·184720 | 0·077232 | 138 | 9·922768 | 20 | 50 |
| 11 | 44 | 9·738241 | 322 | 0·261759 | 9·815555 | 459 | 0·184445 | 0·077314 | 138 | 9·922686 | 16 | 49 |
| 12 | 48 | 9·738434 | 322 | 0·261566 | 9·815831 | 459 | 0·184169 | 0·077397 | 138 | 9·922603 | 12 | 48 |
| 13 | 52 | 9·738627 | 321 | 0·261373 | 9·816107 | 459 | 0·183893 | 0·077480 | 138 | 9·922520 | 8 | 47 |
| 14 | 56 | 9·738820 | 321 | 0·261180 | 9·816382 | 459 | 0·183618 | 0·077562 | 138 | 9·922438 | 4 | 46 |
| 15 | **13** | 9·739013 | 321 | 0·260987 | 9·816658 | 459 | 0·183342 | 0·077645 | 138 | 9·922355 | **47** | 45 |
| 16 | 4 | 9·739206 | 321 | 0·260794 | 9·816933 | 459 | 0·183067 | 0·077728 | 138 | 9·922272 | 56 | 44 |
| 17 | 8 | 9·739398 | 321 | 0·260602 | 9·817209 | 459 | 0·182791 | 0·077811 | 138 | 9·922189 | 52 | 43 |
| 18 | 12 | 9·739590 | 320 | 0·260410 | 9·817484 | 459 | 0·182516 | 0·077894 | 138 | 9·922106 | 48 | 42 |
| 19 | 16 | 9·739783 | 320 | 0·260217 | 9·817759 | 459 | 0·182241 | 0·077977 | 138 | 9·922023 | 44 | 41 |
| 20 | 20 | 9·739975 | 320 | 0·260025 | 9·818035 | 458 | 0·181965 | 0·078060 | 138 | 9·921940 | 40 | 40 |
| 21 | 24 | 9·740167 | 320 | 0·259833 | 9·818310 | 458 | 0·181690 | 0·078143 | 139 | 9·921857 | 36 | 39 |
| 22 | 28 | 9·740359 | 320 | 0·259641 | 9·818585 | 458 | 0·181415 | 0·078226 | 139 | 9·921774 | 32 | 38 |
| 23 | 32 | 9·740550 | 319 | 0·259450 | 9·818860 | 458 | 0·181140 | 0·078309 | 139 | 9·921691 | 28 | 37 |
| 24 | 36 | 9·740742 | 319 | 0·259258 | 9·819135 | 458 | 0·180865 | 0·078393 | 139 | 9·921607 | 24 | 36 |
| 25 | 40 | 9·740934 | 319 | 0·259066 | 9·819410 | 458 | 0·180590 | 0·078476 | 139 | 9·921524 | 20 | 35 |
| 26 | 44 | 9·741125 | 319 | 0·258875 | 9·819684 | 458 | 0·180316 | 0·078559 | 139 | 9·921441 | 16 | 34 |
| 27 | 48 | 9·741316 | 319 | 0·258684 | 9·819959 | 458 | 0·180041 | 0·078643 | 139 | 9·921357 | 12 | 33 |
| 28 | 52 | 9·741508 | 318 | 0·258492 | 9·820234 | 458 | 0·179766 | 0·078726 | 139 | 9·921274 | 8 | 32 |
| 29 | 56 | 9·741699 | 318 | 0·258301 | 9·820508 | 457 | 0·179492 | 0·078810 | 139 | 9·921190 | 4 | 31 |
| 30 | **14** | 9·741889 | 318 | 0·258111 | 9·820783 | 457 | 0·179217 | 0·078893 | 139 | 9·921107 | **46** | 30 |
| 31 | 4 | 9·742080 | 318 | 0·257920 | 9·821057 | 457 | 0·178943 | 0·078977 | 139 | 9·921023 | 56 | 29 |
| 32 | 8 | 9·742271 | 318 | 0·257729 | 9·821332 | 457 | 0·178668 | 0·079061 | 140 | 9·920939 | 52 | 28 |
| 33 | 12 | 9·742462 | 317 | 0·257538 | 9·821606 | 457 | 0·178394 | 0·079144 | 140 | 9·920856 | 48 | 27 |
| 34 | 16 | 9·742652 | 317 | 0·257348 | 9·821880 | 457 | 0·178120 | 0·079228 | 140 | 9·920772 | 44 | 26 |
| 35 | 20 | 9·742842 | 317 | 0·257158 | 9·822154 | 457 | 0·177846 | 0·079312 | 140 | 9·920688 | 40 | 25 |
| 36 | 24 | 9·743033 | 317 | 0·256967 | 9·822429 | 457 | 0·177571 | 0·079396 | 140 | 9·920604 | 36 | 24 |
| 37 | 28 | 9·743223 | 317 | 0·256777 | 9·822703 | 457 | 0·177297 | 0·079480 | 140 | 9·920520 | 32 | 23 |
| 38 | 32 | 9·743413 | 316 | 0·256587 | 9·822977 | 456 | 0·177023 | 0·079564 | 140 | 9·920436 | 28 | 22 |
| 39 | 36 | 9·743602 | 316 | 0·256398 | 9·823251 | 456 | 0·176749 | 0·079648 | 140 | 9·920352 | 24 | 21 |
| 40 | 40 | 9·743792 | 316 | 0·256208 | 9·823524 | 456 | 0·176476 | 0·079732 | 140 | 9·920268 | 20 | 20 |
| 41 | 44 | 9·743982 | 316 | 0·256018 | 9·823798 | 456 | 0·176202 | 0·079816 | 140 | 9·920184 | 16 | 19 |
| 42 | 48 | 9·744171 | 316 | 0·255829 | 9·824072 | 456 | 0·175928 | 0·079901 | 140 | 9·920099 | 12 | 18 |
| 43 | 52 | 9·744361 | 315 | 0·255639 | 9·824345 | 456 | 0·175655 | 0·079985 | 140 | 9·920015 | 8 | 17 |
| 44 | 56 | 9·744550 | 315 | 0·255450 | 9·824619 | 456 | 0·175381 | 0·080069 | 141 | 9·919931 | 4 | 16 |
| 45 | **15** | 9·744739 | 315 | 0·255261 | 9·824893 | 456 | 0·175107 | 0·080154 | 141 | 9·919846 | **45** | 15 |
| 46 | 4 | 9·744928 | 315 | 0·255072 | 9·825166 | 456 | 0·174834 | 0·080238 | 141 | 9·919762 | 56 | 14 |
| 47 | 8 | 9·745117 | 315 | 0·254883 | 9·825439 | 455 | 0·174561 | 0·080323 | 141 | 9·919677 | 52 | 13 |
| 48 | 12 | 9·745306 | 314 | 0·254694 | 9·825713 | 455 | 0·174287 | 0·080407 | 141 | 9·919593 | 48 | 12 |
| 49 | 16 | 9·745494 | 314 | 0·254506 | 9·825986 | 455 | 0·174014 | 0·080492 | 141 | 9·919508 | 44 | 11 |
| 50 | 20 | 9·745683 | 314 | 0·254317 | 9·826259 | 455 | 0·173741 | 0·080576 | 141 | 9·919424 | 40 | 10 |
| 51 | 24 | 9·745871 | 314 | 0·254129 | 9·826532 | 455 | 0·173468 | 0·080661 | 141 | 9·919339 | 36 | 9 |
| 52 | 28 | 9·746060 | 314 | 0·253940 | 9·826805 | 455 | 0·173195 | 0·080746 | 141 | 9·919254 | 32 | 8 |
| 53 | 32 | 9·746248 | 313 | 0·253752 | 9·827078 | 455 | 0·172922 | 0·080831 | 141 | 9·919169 | 28 | 7 |
| 54 | 36 | 9·746436 | 313 | 0·253564 | 9·827351 | 455 | 0·172649 | 0·080915 | 141 | 9·919085 | 24 | 6 |
| 55 | 40 | 9·746624 | 313 | 0·253376 | 9·827624 | 455 | 0·172376 | 0·081000 | 141 | 9·919000 | 20 | 5 |
| 56 | 44 | 9·746812 | 313 | 0·253188 | 9·827897 | 454 | 0·172103 | 0·081085 | 142 | 9·918915 | 16 | 4 |
| 57 | 48 | 9·746999 | 313 | 0·253001 | 9·828170 | 454 | 0·171830 | 0·081170 | 142 | 9·918830 | 12 | 3 |
| 58 | 52 | 9·747187 | 312 | 0·252813 | 9·828442 | 454 | 0·171558 | 0·081255 | 142 | 9·918745 | 8 | 2 |
| 59 | 56 | 9·747374 | 312 | 0·252626 | 9·828715 | 454 | 0·171285 | 0·081341 | 142 | 9·918659 | 4 | 1 |
| 60 | **16** | 9·747562 | | 0·252438 | 9·828987 | | 0·171013 | 0·081426 | | 9·918574 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

123° 56°=3h 44m 56°

## LOG. SINES, COSINES, &c.

34° 34°=2h 16m 145°

| ′ | M. | S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | | 9·747562 | 312 | 0·252438 | 9·828987 | 454 | 0·171013 | 0·081426 | 142 | 9·918574 | 44 | 60 |
| 1 | 4 | | 9·747749 | 312 | 0·252251 | 9 829260 | 454 | 0·170740 | 0·081511 | 142 | 9·918489 | 56 | 59 |
| 2 | 8 | | 9·747936 | 312 | 0·252064 | 9 829532 | 454 | 0·170468 | 0·081596 | 142 | 9 918404 | 52 | 58 |
| 3 | 12 | | 9·748123 | 311 | 0·251877 | 9 829805 | 454 | 0·170195 | 0·081682 | 142 | 9 918318 | 48 | 57 |
| 4 | 16 | | 9·748310 | 311 | 0·251690 | 9 830077 | 454 | 0·169923 | 0·081767 | 142 | 9·918233 | 44 | 56 |
| 5 | 20 | | 9·748497 | 311 | 0·251503 | 9 830349 | 453 | 0·169651 | 0·081853 | 142 | 9 918147 | 40 | 55 |
| 6 | 24 | | 9·748683 | 311 | 0·251317 | 9 830621 | 453 | 0·169379 | 0·081938 | 142 | 9 918062 | 36 | 54 |
| 7 | 28 | | 9·748870 | 311 | 0·251130 | 9 830893 | 453 | 0·169107 | 0·082024 | 143 | 9 917976 | 32 | 53 |
| 8 | 32 | | 9·749056 | 310 | 0·250944 | 9 831165 | 453 | 0·168835 | 0·082109 | 143 | 9 917891 | 28 | 52 |
| 9 | 36 | | 9·749243 | 310 | 0·250757 | 9 831437 | 453 | 0·168563 | 0·082195 | 143 | 9 917805 | 24 | 51 |
| 10 | 40 | | 9·749429 | 310 | 0·250571 | 9 831709 | 453 | 0·168291 | 0·082281 | 143 | 9 917719 | 20 | 50 |
| 11 | 44 | | 9·749615 | 310 | 0·250385 | 9·831981 | 453 | 0·168019 | 0·082366 | 143 | 9·917634 | 16 | 49 |
| 12 | 48 | | 9·749801 | 310 | 0·250199 | 9 832253 | 453 | 0·167747 | 0·082452 | 143 | 9·917548 | 12 | 48 |
| 13 | 52 | | 9·749987 | 309 | 0·250013 | 9·832525 | 453 | 0·167475 | 0·082538 | 143 | 9·917462 | 8 | 47 |
| 14 | 56 | | 9·750172 | 309 | 0·249828 | 9·832796 | 453 | 0·167204 | 0·082624 | 143 | 9·917376 | 4 | 46 |
| 15 | 17 | | 9·750358 | 309 | 0·249642 | 9·833068 | 452 | 0·166932 | 0·082710 | 143 | 9 917290 | 43 | 45 |
| 16 | 4 | | 9·750543 | 309 | 0·249457 | 9 83333g | 452 | 0·166661 | 0·082796 | 143 | 9 917204 | 56 | 44 |
| 17 | 8 | | 9·750729 | 309 | 0·249271 | 9 833611 | 452 | 0·166389 | 0·082882 | 144 | 9 917118 | 52 | 43 |
| 18 | 12 | | 9·750914 | 308 | 0·249086 | 9 833882 | 452 | 0·166118 | 0·082968 | 144 | 9 917032 | 48 | 42 |
| 19 | 16 | | 9·751099 | 308 | 0·248901 | 9 834154 | 452 | 0·165846 | 0·083054 | 144 | 9 916946 | 44 | 41 |
| 20 | 20 | | 9·751284 | 308 | 0·248716 | 9 834425 | 452 | 0·165575 | 0·083141 | 144 | 9 916859 | 40 | 40 |
| 21 | 24 | | 9·751469 | 308 | 0·248531 | 9 834696 | 452 | 0·165304 | 0·083227 | 144 | 9 916773 | 36 | 39 |
| 22 | 28 | | 9·751654 | 308 | 0·248346 | 9 834967 | 452 | 0·165033 | 0·083313 | 144 | 9 916687 | 32 | 38 |
| 23 | 32 | | 9·751839 | 308 | 0·248161 | 9·835238 | 452 | 0·164762 | 0·083400 | 144 | 9 916600 | 28 | 37 |
| 24 | 36 | | 9·752023 | 307 | 0·247977 | 9·835509 | 452 | 0·164491 | 0·083486 | 144 | 9 916514 | 24 | 36 |
| 25 | 40 | | 9·752208 | 307 | 0·247792 | 9 835780 | 451 | 0·164220 | 0·083573 | 144 | 9 916427 | 20 | 35 |
| 26 | 44 | | 9·752392 | 307 | 0·247608 | 9·836051 | 451 | 0·163949 | 0·083659 | 144 | 9·916341 | 16 | 34 |
| 27 | 48 | | 9·752576 | 307 | 0·247424 | 9 836322 | 451 | 0·163678 | 0·083746 | 144 | 9·916254 | 12 | 33 |
| 28 | 52 | | 9·752760 | 307 | 0·247240 | 9 836593 | 451 | 0·163407 | 0·083833 | 144 | 9 916167 | 8 | 32 |
| 29 | 56 | | 9·752944 | 306 | 0·247056 | 9·836864 | 451 | 0·163136 | 0·083919 | 145 | 9 916081 | 4 | 31 |
| 30 | 18 | | 9·753128 | 306 | 0·246872 | 9·837134 | 451 | 0·162866 | 0·084006 | 145 | 9 915994 | 42 | 30 |
| 31 | 4 | | 9·753312 | 306 | 0·246688 | 9 837405 | 451 | 0·162595 | 0·084093 | 145 | 9 915907 | 56 | 29 |
| 32 | 8 | | 9·753495 | 306 | 0·246505 | 9 837675 | 451 | 0·162325 | 0·084180 | 145 | 9·915820 | 52 | 28 |
| 33 | 12 | | 9·753679 | 306 | 0·246321 | 9 837946 | 451 | 0·162054 | 0·084267 | 145 | 9 915733 | 48 | 27 |
| 34 | 16 | | 9·753862 | 305 | 0·246138 | 9·838216 | 451 | 0·161784 | 0·084354 | 145 | 9 915646 | 44 | 26 |
| 35 | 20 | | 9·754046 | 305 | 0·245954 | 9 838487 | 450 | 0·161513 | 0·084441 | 145 | 9 915559 | 40 | 25 |
| 36 | 24 | | 9·754229 | 305 | 0·245771 | 9 838757 | 450 | 0·161243 | 0·084528 | 145 | 9 915472 | 36 | 24 |
| 37 | 28 | | 9·754412 | 305 | 0·245588 | 9·839027 | 450 | 0·160973 | 0·084615 | 145 | 9 915385 | 32 | 23 |
| 38 | 32 | | 9·754595 | 305 | 0·245405 | 9·839297 | 450 | 0·160703 | 0·084703 | 145 | 9 915297 | 28 | 22 |
| 39 | 36 | | 9·754778 | 304 | 0·245222 | 9·839568 | 450 | 0·160432 | 0·084790 | 145 | 9 915210 | 24 | 21 |
| 40 | 40 | | 9·754960 | 304 | 0·245040 | 9 839838 | 450 | 0·160162 | 0·084877 | 145 | 9 915123 | 20 | 20 |
| 41 | 44 | | 9·755143 | 304 | 0·244857 | 9 840108 | 450 | 0·159892 | 0·084965 | 146 | 9 915035 | 16 | 19 |
| 42 | 48 | | 9·755326 | 304 | 0·244674 | 9 840378 | 450 | 0·159622 | 0·085052 | 146 | 9·914948 | 12 | 18 |
| 43 | 52 | | 9·755508 | 304 | 0·244492 | 9·840647 | 450 | 0·159353 | 0·085140 | 146 | 9 914860 | 8 | 17 |
| 44 | 56 | | 9·755690 | 304 | 0·244310 | 9·840917 | 449 | 0·159083 | 0·085227 | 146 | 9 914773 | 4 | 16 |
| 45 | 19 | | 9·755872 | 303 | 0·244128 | 9·841187 | 449 | 0·158813 | 0·085315 | 146 | 9 914685 | 41 | 15 |
| 46 | 4 | | 9·756054 | 303 | 0·243946 | 9·841457 | 449 | 0·158543 | 0·085402 | 146 | 9 914598 | 56 | 14 |
| 47 | 8 | | 9·756236 | 303 | 0·243764 | 9 841726 | 449 | 0·158274 | 0·085490 | 146 | 9 914510 | 52 | 13 |
| 48 | 12 | | 9·756418 | 303 | 0·243582 | 9 841996 | 449 | 0·158004 | 0·085578 | 146 | 9 914422 | 48 | 12 |
| 49 | 16 | | 9·756600 | 303 | 0·243400 | 9 842266 | 449 | 0·157734 | 0·085666 | 146 | 9·914334 | 44 | 11 |
| 50 | 20 | | 9·756782 | 302 | 0·243218 | 9 842535 | 449 | 0·157465 | 0·085754 | 147 | 9·914246 | 40 | 10 |
| 51 | 24 | | 9·756963 | 302 | 0·243037 | 9 842805 | 449 | 0·157195 | 0·085842 | 147 | 9·914158 | 36 | 9 |
| 52 | 28 | | 9·757144 | 302 | 0·242856 | 9 843074 | 449 | 0·156926 | 0·085930 | 147 | 9 914070 | 32 | 8 |
| 53 | 32 | | 9·757326 | 302 | 0·242674 | 9 843343 | 449 | 0·156657 | 0·086018 | 147 | 9 913982 | 28 | 7 |
| 54 | 36 | | 9·757507 | 302 | 0·242493 | 9 843612 | 449 | 0·156388 | 0·086106 | 147 | 9 913894 | 24 | 6 |
| 55 | 40 | | 9·757688 | 301 | 0·242312 | 9·843882 | 448 | 0·156118 | 0·086194 | 147 | 9·913806 | 20 | 5 |
| 56 | 44 | | 9·757869 | 301 | 0·242131 | 9 844151 | 448 | 0·155849 | 0·086282 | 147 | 9·913718 | 16 | 4 |
| 57 | 48 | | 9·758050 | 301 | 0·241950 | 9 844420 | 448 | 0·155580 | 0·086370 | 147 | 9 913630 | 12 | 3 |
| 58 | 52 | | 9·758230 | 301 | 0·241770 | 9 844689 | 448 | 0·155311 | 0·086459 | 147 | 9 913541 | 8 | 2 |
| 59 | 56 | | 9·758411 | 301 | 0·241589 | 9 844958 | 448 | 0·155042 | 0·086547 | 147 | 9 913453 | 4 | 1 |
| 60 | 20 | | 9·758591 | | 0·241409 | 9·845227 | | 0·154773 | 0·086635 | 147 | 9·913365 | 0 | 0 |
| ′ | | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | S. M. | ′ |

124° 55°=3h 40m 55°

## LOG. SINES, COSINES, &c.

35° 35°=2h 20m 144°

| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·758591 | 301 | 0·241409 | 9·845227 | 448 | 0·154773 | 0·086635 | 147 | 9·913365 | 40 | 60 |
| 1 | 4 | 9·758772 | 300 | 0·241228 | 9·845496 | 448 | 0·154504 | 0·086724 | 147 | 9·913276 | 56 | 59 |
| 2 | 8 | 9·758952 | 300 | 0·241048 | 9 845764 | 448 | 0·154236 | 0·086813 | 148 | 9 913187 | 52 | 58 |
| 3 | 12 | 9·759132 | 300 | 0·240868 | 9 846033 | 448 | 0·153967 | 0·086901 | 148 | 9 913099 | 48 | 57 |
| 4 | 16 | 9·759312 | 300 | 0·240688 | 9 846302 | 448 | 0·153698 | 0·086990 | 148 | 9·913010 | 44 | 56 |
| 5 | 20 | 9·759492 | 300 | 0·240508 | 9 846570 | 447 | 0·153430 | 0·087078 | 148 | 9·912922 | 40 | 55 |
| 6 | 24 | 9·759672 | 299 | 0·240328 | 9 846839 | 447 | 0·153161 | 0·087167 | 148 | 9 912833 | 36 | 54 |
| 7 | 28 | 9·759852 | 299 | 0·240148 | 9·847108 | 447 | 0·152892 | 0·087256 | 148 | 9·912744 | 32 | 53 |
| 8 | 32 | 9·760031 | 299 | 0·239969 | 9·847376 | 447 | 0·152624 | 0·087345 | 148 | 9 912655 | 28 | 52 |
| 9 | 36 | 9·760211 | 299 | 0·239789 | 9·847644 | 447 | 0·152356 | 0·087434 | 148 | 9 912566 | 24 | 51 |
| 10 | 40 | 9·760390 | 299 | 0·239610 | 9·847913 | 447 | 0·152087 | 0·087523 | 148 | 9 912477 | 20 | 50 |
| 11 | 44 | 9·760569 | 298 | 0·239431 | 9·848181 | 447 | 0·151819 | 0·087612 | 148 | 9·912388 | 16 | 49 |
| 12 | 48 | 9·760748 | 298 | 0·239252 | 9·848449 | 447 | 0·151551 | 0·087701 | 149 | 9·912299 | 12 | 48 |
| 13 | 52 | 9·760927 | 298 | 0·239073 | 9·848717 | 447 | 0·151283 | 0·087790 | 149 | 9·912210 | 8 | 47 |
| 14 | 56 | 9·761106 | 298 | 0·238894 | 9·848986 | 447 | 0·151014 | 0·087879 | 149 | 9 912121 | 4 | 46 |
| 15 | 21 | 9·761285 | 298 | 0·238715 | 9 849254 | 447 | 0·150746 | 0·087969 | 149 | 9 912031 | 39 | 45 |
| 16 | 4 | 9·761464 | 298 | 0·238536 | 9 849522 | 447 | 0·150478 | 0·088058 | 149 | 9 911942 | 56 | 44 |
| 17 | 8 | 9·761642 | 298 | 0·238358 | 9·849790 | 447 | 0·150210 | 0·088147 | 149 | 9 911853 | 52 | 43 |
| 18 | 12 | 9·761821 | 297 | 0·238179 | 9 850057 | 446 | 0·149943 | 0·088237 | 149 | 9 911763 | 48 | 42 |
| 19 | 16 | 9·761999 | 297 | 0·238001 | 9 850325 | 446 | 0·149675 | 0·088326 | 149 | 9 911674 | 44 | 41 |
| 20 | 20 | 9·762177 | 297 | 0·237823 | 9 850593 | 446 | 0·149407 | 0·088416 | 149 | 9 911584 | 40 | 40 |
| 21 | 24 | 9·762356 | 297 | 0·237644 | 9·850861 | 446 | 0·149139 | 0·088505 | 149 | 9 911495 | 36 | 39 |
| 22 | 28 | 9·762534 | 296 | 0·237466 | 9 851129 | 446 | 0·148871 | 0·088595 | 149 | 9·911405 | 32 | 38 |
| 23 | 32 | 9·762712 | 296 | 0·237288 | 9·851396 | 446 | 0·148604 | 0·088685 | 149 | 9 911315 | 28 | 37 |
| 24 | 36 | 9·762889 | 296 | 0·237111 | 9·851664 | 446 | 0·148336 | 0 088774 | 150 | 9 911226 | 24 | 36 |
| 25 | 40 | 9·763067 | 296 | 0·236933 | 9 851931 | 446 | 0·148069 | 0 088864 | 150 | 9 911136 | 20 | 35 |
| 26 | 44 | 9 763245 | 296 | 0·236755 | 9·852199 | 446 | 0·147801 | 0·088954 | 150 | 9 911046 | 16 | 34 |
| 27 | 48 | 9 763422 | 296 | 0·236578 | 9·852466 | 446 | 0·147534 | 0·089044 | 150 | 9·910956 | 12 | 33 |
| 28 | 52 | 9 763600 | 296 | 0·236400 | 9 852733 | 446 | 0·147267 | 0·089134 | 150 | 9 910866 | 8 | 32 |
| 29 | 56 | 9·763777 | 295 | 0·236223 | 9·853001 | 445 | 0·146999 | 0 089224 | 150 | 9 910776 | 4 | 31 |
| 30 | 22 | 9·763954 | 295 | 0·236046 | 9·853268 | 445 | 0·146732 | 0 089314 | 150 | 9 910686 | 38 | 30 |
| 31 | 4 | 9·764131 | 295 | 0·235869 | 9·853535 | 445 | 0 146465 | 0 089404 | 150 | 9 910596 | 56 | 29 |
| 32 | 8 | 9·764308 | 295 | 0·235692 | 9 853802 | 445 | 0 146198 | 0 089494 | 150 | 9·910506 | 52 | 28 |
| 33 | 12 | 9·764485 | 294 | 0·235515 | 9 854069 | 445 | 0 145931 | 0·089585 | 150 | 9 910415 | 48 | 27 |
| 34 | 16 | 9·764662 | 294 | 0·235338 | 9·854336 | 445 | 0 145664 | 0 089675 | 151 | 9 910325 | 44 | 26 |
| 35 | 20 | 9·764838 | 294 | 0·235162 | 9 854603 | 445 | 0 145397 | 0·089765 | 151 | 9 910235 | 40 | 25 |
| 36 | 24 | 9·765015 | 294 | 0·234985 | 9 854870 | 445 | 0 145130 | 0 089856 | 151 | 9 910144 | 36 | 24 |
| 37 | 28 | 9·765191 | 294 | 0·234809 | 9·855137 | 445 | 0·144863 | 0 089946 | 151 | 9 910054 | 32 | 23 |
| 38 | 32 | 9·765367 | 294 | 0·234633 | 9·855404 | 445 | 0·144596 | 0 090037 | 151 | 9 909963 | 28 | 22 |
| 39 | 36 | 9·765544 | 294 | 0·234456 | 9·855671 | 445 | 0·144329 | 0 090127 | 151 | 9 909873 | 24 | 21 |
| 40 | 40 | 9 765720 | 293 | 0·234280 | 9 855938 | 444 | 0 144062 | 0 090218 | 151 | 9 909782 | 20 | 20 |
| 41 | 44 | 9·765896 | 293 | 0·234104 | 9 856204 | 444 | 0 143796 | 0 090309 | 151 | 9 909691 | 16 | 19 |
| 42 | 48 | 9 766072 | 293 | 0·233928 | 9 856471 | 444 | 0 143529 | 0 090399 | 151 | 9 909601 | 12 | 18 |
| 43 | 52 | 9·766247 | 293 | 0·233753 | 9·856737 | 444 | 0 143263 | 0 090490 | 151 | 9 909510 | 8 | 17 |
| 44 | 56 | 9·766423 | 293 | 0·233577 | 9·857004 | 444 | 0 142996 | 0 090581 | 151 | 9 909419 | 4 | 16 |
| 45 | 23 | 9·766598 | 292 | 0·233402 | 9·857270 | 444 | 0·142730 | 0 090672 | 152 | 9 909328 | 37 | 15 |
| 46 | 4 | 9·766774 | 292 | 0·233226 | 9·857537 | 444 | 0·142463 | 0·090763 | 152 | 9 909237 | 56 | 14 |
| 47 | 8 | 9·766949 | 292 | 0·233051 | 9·857803 | 444 | 0·142197 | 0 090854 | 152 | 9 909146 | 52 | 13 |
| 48 | 12 | 9·767124 | 292 | 0·232876 | 9 858069 | 444 | 0·141931 | 0 090945 | 152 | 9 909055 | 48 | 12 |
| 49 | 16 | 9·767300 | 292 | 0·232700 | 9·858336 | 444 | 0·141664 | 0 091036 | 152 | 9 908964 | 44 | 11 |
| 50 | 20 | 9·767475 | 291 | 0·232525 | 9·858602 | 443 | 0·141398 | 0 091127 | 152 | 9 908873 | 40 | 10 |
| 51 | 24 | 9·767649 | 291 | 0·232351 | 9 858868 | 443 | 0·141132 | 0·091219 | 152 | 9 908781 | 36 | 9 |
| 52 | 28 | 9·767824 | 291 | 0·232176 | 9·859134 | 443 | 0·140866 | 0 091310 | 152 | 9 908690 | 32 | 8 |
| 53 | 32 | 9·767999 | 291 | 0·232001 | 9 859400 | 443 | 0·140600 | 0·091401 | 152 | 9 908599 | 28 | 7 |
| 54 | 36 | 9·768173 | 291 | 0·231827 | 9·859666 | 443 | 0·140334 | 0·091493 | 152 | 9 908507 | 24 | 6 |
| 55 | 40 | 9·768348 | 290 | 0·231652 | 9·859932 | 443 | 0·140068 | 0·091584 | 153 | 9 908416 | 20 | 5 |
| 56 | 44 | 9·768522 | 290 | 0·231478 | 9·860198 | 443 | 0·139802 | 0 091676 | 153 | 9 908324 | 16 | 4 |
| 57 | 48 | 9·768697 | 290 | 0·231303 | 9·860464 | 443 | 0·139536 | 0·091767 | 153 | 9 908233 | 12 | 3 |
| 58 | 52 | 9·768871 | 290 | 0·231129 | 9·860730 | 443 | 0·139270 | 0 091859 | 153 | 9 908141 | 8 | 2 |
| 59 | 56 | 9·769045 | 290 | 0·230955 | 9 860995 | 443 | 0·139005 | 0·091951 | 153 | 9 908049 | 4 | 1 |
| 60 | 24 | 9·769219 | 290 | 0·230781 | 9·861261 | 443 | 0·138739 | 0·092042 | 153 | 9 907958 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

125° 54°=3h 36m 54°

## LOG. SINES, COSINES, &c.

36° 36°=2h 24m 143°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·769219 | 290 | 0·230781 | 9·861261 | 443 | 0·138739 | 0·092042 | 153 | 9·907958 | **36** | 60 |
| 1 | 4 | 9·769393 | 289 | 0·230607 | 9·861527 | 443 | 0·138473 | 0·092134 | 153 | 9·907866 | 56 | 59 |
| 2 | 8 | 9·769566 | 289 | 0·230434 | 9 861792 | 442 | 0·138208 | 0·092226 | 153 | 9·907774 | 52 | 58 |
| 3 | 12 | 9·769740 | 289 | 0·230260 | 9 862058 | 442 | 0·137942 | 0·092318 | 153 | 9·907682 | 48 | 57 |
| 4 | 16 | 9·769913 | 289 | 0·230087 | 9·862323 | 442 | 0·137677 | 0·092410 | 153 | 9·907590 | 44 | 56 |
| 5 | 20 | 9·770087 | 289 | 0·229913 | 9·862589 | 442 | 0·137411 | 0·092502 | 153 | 9·907498 | 40 | 55 |
| 6 | 24 | 9·770260 | 288 | 0·229740 | 9 862854 | 442 | 0·137146 | 0·092594 | 153 | 9·907406 | 36 | 54 |
| 7 | 28 | 9·770433 | 288 | 0·229567 | 9·863119 | 442 | 0·136881 | 0·092686 | 154 | 9 907314 | 32 | 53 |
| 8 | 32 | 9·770606 | 288 | 0·229394 | 9 863385 | 442 | 0·136615 | 0·092778 | 154 | 9 907222 | 28 | 52 |
| 9 | 36 | 9·770779 | 288 | 0·229221 | 9·863650 | 442 | 0·136350 | 0·092871 | 154 | 9 907129 | 24 | 51 |
| 10 | 40 | 9·770952 | 288 | 0·229048 | 9·863915 | 442 | 0·136085 | 0·092963 | 154 | 9·907037 | 20 | 50 |
| 11 | 44 | 9·771125 | 288 | 0·228875 | 9·864180 | 442 | 0·135820 | 0·093055 | 154 | 9·906945 | 16 | 49 |
| 12 | 48 | 9·771298 | 287 | 0·228702 | 9·864445 | 442 | 0·135555 | 0·093148 | 154 | 9 906852 | 12 | 48 |
| 13 | 52 | 9·771470 | 287 | 0·228530 | 9·864710 | 442 | 0·135290 | 0·093240 | 154 | 9 906760 | 8 | 47 |
| 14 | 56 | 9·771643 | 287 | 0·228357 | 9·864975 | 442 | 0·135025 | 0·093333 | 154 | 9 906667 | 4 | 46 |
| 15 | **25** | 9·771815 | 287 | 0·228185 | 9 865240 | 441 | 0·134760 | 0·093425 | 154 | 9 906575 | **35** | 45 |
| 16 | 4 | 9·771987 | 287 | 0 228013 | 9 865505 | 441 | 0·134495 | 0 093518 | 154 | 9·906482 | 56 | 44 |
| 17 | 8 | 9·772159 | 287 | 0·227841 | 9 865770 | 441 | 0·134230 | 0·093611 | 154 | 9·906389 | 52 | 43 |
| 18 | 12 | 9·772331 | 286 | 0·227669 | 9 866035 | 441 | 0·133965 | 0 093704 | 155 | 9 906296 | 48 | 42 |
| 19 | 16 | 9·772503 | 286 | 0·227497 | 9 866300 | 441 | 0·133700 | 0·093796 | 155 | 9 906204 | 44 | 41 |
| 20 | 20 | 9·772675 | 286 | 0·227325 | 9·866564 | 441 | 0·133436 | 0·093889 | 155 | 9 906111 | 40 | 40 |
| 21 | 24 | 9·772847 | 286 | 0·227153 | 9 866829 | 441 | 0·133171 | 0·093982 | 155 | 9 906018 | 36 | 39 |
| 22 | 28 | 9·773018 | 286 | 0·226982 | 9 867094 | 441 | 0·132906 | 0·094075 | 155 | 9 905925 | 32 | 38 |
| 23 | 32 | 9·773190 | 286 | 0·226810 | 9·867358 | 441 | 0·132642 | 0·094168 | 155 | 9 905832 | 28 | 37 |
| 24 | 36 | 9·773361 | 285 | 0·226639 | 9·867623 | 441 | 0·132377 | 0 094261 | 155 | 9 905739 | 24 | 36 |
| 25 | 40 | 9·773533 | 285 | 0·226467 | 9 867887 | 441 | 0·132113 | 0 094355 | 155 | 9 905645 | 20 | 35 |
| 26 | 44 | 9·773704 | 285 | 0·226296 | 9 868152 | 440 | 0·131848 | 0·094448 | 155 | 9 905552 | 16 | 34 |
| 27 | 48 | 9·773875 | 285 | 0·226125 | 9 868416 | 440 | 0·131584 | 0 094541 | 155 | 9 905459 | 12 | 33 |
| 28 | 52 | 9·774046 | 285 | 0·225954 | 9·868680 | 440 | 0·131320 | 0 094634 | 155 | 9 905366 | 8 | 32 |
| 29 | 56 | 9·774217 | 285 | 0·225783 | 9 868945 | 440 | 0·131055 | 0 094728 | 156 | 9 905272 | 4 | 31 |
| 30 | **26** | 9·774388 | 284 | 0·225612 | 9·869209 | 440 | 0·130791 | 0 094821 | 156 | 9 905179 | **34** | 30 |
| 31 | 4 | 9 774558 | 284 | 0·225442 | 9 869473 | 440 | 0·130527 | 0 094915 | 156 | 9 905085 | 56 | 29 |
| 32 | 8 | 9·774729 | 284 | 0·225271 | 9 869737 | 440 | 0·130263 | 0·095008 | 156 | 9 904992 | 52 | 28 |
| 33 | 12 | 9·774899 | 284 | 0·225101 | 9 870001 | 440 | 0 129999 | 0 095102 | 156 | 9 904898 | 48 | 27 |
| 34 | 16 | 9·775070 | 284 | 0·224930 | 9·870265 | 440 | 0·129735 | 0 095196 | 156 | 9 904804 | 44 | 26 |
| 35 | 20 | 9·775240 | 284 | 0·224760 | 9·870529 | 440 | 0·129471 | 0·095289 | 156 | 9 904711 | 40 | 25 |
| 36 | 24 | 9·775410 | 283 | 0·224590 | 9 870793 | 440 | 0·129207 | 0 095383 | 156 | 9 904617 | 36 | 24 |
| 37 | 28 | 9·775580 | 283 | 0·224420 | 9·871057 | 440 | 0·128943 | 0 095477 | 156 | 9 904523 | 32 | 23 |
| 38 | 32 | 9·775750 | 283 | 0·224250 | 9·871321 | 440 | 0·128679 | 0 095571 | 157 | 9 904429 | 28 | 22 |
| 39 | 36 | 9·775920 | 283 | 0·224080 | 9 871585 | 440 | 0·128415 | 0 095665 | 157 | 9 904335 | 24 | 21 |
| 40 | 40 | 9·776090 | 283 | 0 223910 | 9 871849 | 439 | 0·128151 | 0 095759 | 157 | 9 904241 | 20 | 20 |
| 41 | 44 | 9·776259 | 283 | 0·223741 | 9·872112 | 439 | 0·127888 | 0 095853 | 157 | 9 904147 | 16 | 19 |
| 42 | 48 | 9·776429 | 282 | 0·223571 | 9 872376 | 439 | 0·127624 | 0 095947 | 157 | 9 904053 | 12 | 18 |
| 43 | 52 | 9·776598 | 282 | 0·223402 | 9·872640 | 439 | 0·127360 | 0 096041 | 157 | 9 903959 | 8 | 17 |
| 44 | 56 | 9·776768 | 282 | 0·223232 | 9·872903 | 439 | 0·127097 | 0 096136 | 157 | 9 903864 | 4 | 16 |
| 45 | **27** | 9·776937 | 282 | 0·223063 | 9 873167 | 439 | 0·126833 | 0·096230 | 157 | 9 903770 | **33** | 15 |
| 46 | 4 | 9·777106 | 282 | 0·222894 | 9 873430 | 439 | 0·126570 | 0 096324 | 157 | 9 903676 | 56 | 14 |
| 47 | 8 | 9·777275 | 281 | 0·222725 | 9 873694 | 439 | 0·126306 | 0 096419 | 157 | 9 903581 | 52 | 13 |
| 48 | 12 | 9·777444 | 281 | 0·222556 | 9 873957 | 439 | 0·126043 | 0 096513 | 157 | 9 903487 | 48 | 12 |
| 49 | 16 | 9·777613 | 281 | 0·222387 | 9 874220 | 439 | 0·125780 | 0 096608 | 158 | 9 903392 | 44 | 11 |
| 50 | 20 | 9·777781 | 281 | 0·222219 | 9 874484 | 439 | 0 125516 | 0 096702 | 158 | 9 903298 | 40 | 10 |
| 51 | 24 | 9·777950 | 281 | 0·222050 | 9 874747 | 439 | 0 125253 | 0 096797 | 158 | 9 903203 | 36 | 9 |
| 52 | 28 | 9·778119 | 281 | 0·221881 | 9 875010 | 439 | 0·124990 | 0 096892 | 158 | 9 903108 | 32 | 8 |
| 53 | 32 | 9·778287 | 280 | 0·221713 | 9·875273 | 438 | 0·124727 | 0 096986 | 158 | 9 903014 | 28 | 7 |
| 54 | 36 | 9·778455 | 280 | 0·221545 | 9 875537 | 438 | 0·124463 | 0 097081 | 158 | 9 902919 | 24 | 6 |
| 55 | 40 | 9·778624 | 280 | 0·221376 | 9 875800 | 438 | 0·124200 | 0 097176 | 158 | 9 902824 | 20 | 5 |
| 56 | 44 | 9·778792 | 280 | 0·221208 | 9 876063 | 438 | 0·123937 | 0 097271 | 158 | 9 902729 | 16 | 4 |
| 57 | 48 | 9·778960 | 280 | 0·221040 | 9 876326 | 438 | 0·123674 | 0 097366 | 158 | 9 902634 | 12 | 3 |
| 58 | 52 | 9·779128 | 280 | 0·220872 | 9 876589 | 438 | 0·123411 | 0 097461 | 159 | 9 902539 | 8 | 2 |
| 59 | 56 | 9·779295 | 279 | 0·220705 | 9 876851 | 438 | 0·123149 | 0 097556 | 159 | 9 902444 | 4 | 1 |
| 60 | **28** | 9·779463 | | 0·220537 | 9·877114 | | 0·122886 | 0 097651 | | 9 902349 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

126° 53°=3h 32m 53°

## LOG. SINES, COSINES, &c.

37° 37°=2h 28m 142°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·779463 | 279 | 0·220537 | 9·877114 | 438 | 0·122886 | 0·097651 | 159 | 9·902349 | 32 | 60 |
| 1 | 4 | 9·779631 | 279 | 0·220369 | 9·877377 | 438 | 0·122623 | 0·097747 | 159 | 9·902253 | 56 | 59 |
| 2 | 8 | 9·779798 | 279 | 0·220202 | 9·877640 | 438 | 0·122360 | 0·097842 | 159 | 9·902158 | 52 | 58 |
| 3 | 12 | 9·779966 | 279 | 0·220034 | 9·877903 | 438 | 0·122097 | 0·097937 | 159 | 9·902063 | 48 | 57 |
| 4 | 16 | 9·780133 | 279 | 0·219867 | 9·878165 | 438 | 0·121835 | 0·098033 | 159 | 9·901967 | 44 | 56 |
| 5 | 20 | 9·780300 | 278 | 0·219700 | 9·878428 | 438 | 0·121572 | 0·098128 | 159 | 9·901872 | 40 | 55 |
| 6 | 24 | 9·780467 | 278 | 0·219533 | 9·878691 | 438 | 0·121309 | 0·098224 | 159 | 9·901776 | 36 | 54 |
| 7 | 28 | 9·780634 | 278 | 0·219366 | 9·878953 | 437 | 0·121047 | 0·098319 | 159 | 9·901681 | 32 | 53 |
| 8 | 32 | 9·780801 | 278 | 0·219199 | 9·879216 | 437 | 0·120784 | 0·098415 | 159 | 9·901585 | 28 | 52 |
| 9 | 36 | 9·780968 | 278 | 0·219032 | 9·879478 | 437 | 0·120522 | 0·098510 | 159 | 9·901490 | 24 | 51 |
| 10 | 40 | 9·781134 | 278 | 0·218866 | 9·879741 | 437 | 0·120259 | 0·098606 | 160 | 9·901394 | 20 | 50 |
| 11 | 44 | 9·781301 | 277 | 0·218699 | 9·880003 | 437 | 0·119997 | 0·098702 | 160 | 9·901298 | 16 | 49 |
| 12 | 48 | 9·781468 | 277 | 0·218532 | 9·880265 | 437 | 0·119735 | 0·098798 | 160 | 9·901202 | 12 | 48 |
| 13 | 52 | 9·781634 | 277 | 0·218366 | 9·880528 | 437 | 0·119472 | 0·098894 | 160 | 9·901106 | 8 | 47 |
| 14 | 56 | 9·781800 | 277 | 0·218200 | 9·880790 | 437 | 0·119210 | 0·098990 | 160 | 9·901010 | 4 | 46 |
| 15 | 29 | 9·781966 | 277 | 0·218034 | 9·881052 | 437 | 0·118948 | 0·099086 | 160 | 9·900914 | 31 | 45 |
| 16 | 4 | 9·782132 | 277 | 0·217868 | 9·881314 | 437 | 0·118686 | 0·099182 | 160 | 9·900818 | 56 | 44 |
| 17 | 8 | 9·782298 | 277 | 0·217702 | 9·881577 | 437 | 0·118423 | 0·099278 | 160 | 9·900722 | 52 | 43 |
| 18 | 12 | 9·782464 | 276 | 0·217536 | 9·881839 | 437 | 0·118161 | 0·099374 | 160 | 9·900626 | 48 | 42 |
| 19 | 16 | 9·782630 | 276 | 0·217370 | 9·882101 | 437 | 0·117899 | 0·099471 | 160 | 9·900529 | 44 | 41 |
| 20 | 20 | 9·782796 | 276 | 0·217204 | 9·882363 | 437 | 0·117637 | 0·099567 | 160 | 9·900433 | 40 | 40 |
| 21 | 24 | 9·782961 | 276 | 0·217039 | 9·882625 | 436 | 0·117375 | 0·099663 | 161 | 9·900337 | 36 | 39 |
| 22 | 28 | 9·783127 | 276 | 0·216873 | 9·882887 | 436 | 0·117113 | 0·099760 | 161 | 9·900240 | 32 | 38 |
| 23 | 32 | 9·783292 | 275 | 0·216708 | 9·883148 | 436 | 0·116852 | 0·099856 | 161 | 9·900144 | 28 | 37 |
| 24 | 36 | 9·783458 | 275 | 0·216542 | 9·883410 | 436 | 0·116590 | 0·099953 | 161 | 9·900047 | 24 | 36 |
| 25 | 40 | 9·783623 | 275 | 0·216377 | 9·883672 | 436 | 0·116328 | 0·100049 | 161 | 9·899951 | 20 | 35 |
| 26 | 44 | 9·783788 | 275 | 0·216212 | 9·883934 | 436 | 0·116066 | 0·100146 | 161 | 9·899854 | 16 | 34 |
| 27 | 48 | 9·783953 | 275 | 0·216047 | 9·884196 | 436 | 0·115804 | 0·100243 | 161 | 9·899757 | 12 | 33 |
| 28 | 52 | 9·784118 | 275 | 0·215882 | 9·884457 | 436 | 0·115543 | 0·100340 | 161 | 9·899660 | 8 | 32 |
| 29 | 56 | 9·784282 | 274 | 0·215718 | 9·884719 | 436 | 0·115281 | 0·100436 | 161 | 9·899564 | 4 | 31 |
| 30 | 30 | 9·784447 | 274 | 0·215553 | 9·884980 | 436 | 0·115020 | 0·100533 | 161 | 9·899467 | 30 | 30 |
| 31 | 4 | 9·784612 | 274 | 0·215388 | 9·885242 | 436 | 0·114758 | 0·100630 | 162 | 9·899370 | 56 | 29 |
| 32 | 8 | 9·784776 | 274 | 0·215224 | 9·885504 | 436 | 0·114496 | 0·100727 | 162 | 9·899273 | 52 | 28 |
| 33 | 12 | 9·784941 | 274 | 0·215059 | 9·885765 | 436 | 0·114235 | 0·100824 | 162 | 9·899176 | 48 | 27 |
| 34 | 16 | 9·785105 | 274 | 0·214895 | 9·886026 | 436 | 0·113974 | 0·100922 | 162 | 9·899078 | 44 | 26 |
| 35 | 20 | 9·785269 | 274 | 0·214731 | 9·886288 | 436 | 0·113712 | 0·101019 | 162 | 9·898981 | 40 | 25 |
| 36 | 24 | 9·785433 | 273 | 0·214567 | 9·886549 | 436 | 0·113451 | 0·101116 | 162 | 9·898884 | 36 | 24 |
| 37 | 28 | 9·785597 | 273 | 0·214403 | 9·886811 | 435 | 0·113189 | 0·101213 | 162 | 9·898787 | 32 | 23 |
| 38 | 32 | 9·785761 | 273 | 0·214239 | 9·887072 | 435 | 0·112928 | 0·101311 | 162 | 9·898689 | 28 | 22 |
| 39 | 36 | 9·785925 | 273 | 0·214075 | 9·887333 | 435 | 0·112667 | 0·101408 | 162 | 9·898592 | 24 | 21 |
| 40 | 40 | 9·786089 | 273 | 0·213911 | 9·887594 | 435 | 0·112406 | 0·101506 | 163 | 9·898494 | 20 | 20 |
| 41 | 44 | 9·786252 | 272 | 0·213748 | 9·887855 | 435 | 0·112145 | 0·101603 | 163 | 9·898397 | 16 | 19 |
| 42 | 48 | 9·786416 | 272 | 0·213584 | 9·888116 | 435 | 0·111884 | 0·101701 | 163 | 9·898299 | 12 | 18 |
| 43 | 52 | 9·786579 | 272 | 0·213421 | 9·888378 | 435 | 0·111622 | 0·101798 | 163 | 9·898202 | 8 | 17 |
| 44 | 56 | 9·786742 | 272 | 0·213258 | 9·888639 | 435 | 0·111361 | 0·101896 | 163 | 9·898104 | 4 | 16 |
| 45 | 31 | 9·786906 | 272 | 0·213094 | 9·888900 | 435 | 0·111100 | 0·101994 | 163 | 9·898006 | 29 | 15 |
| 46 | 4 | 9·787069 | 272 | 0·212931 | 9·889161 | 435 | 0·110839 | 0·102092 | 163 | 9·897908 | 56 | 14 |
| 47 | 8 | 9·787232 | 272 | 0·212768 | 9·889421 | 435 | 0·110579 | 0·102190 | 163 | 9·897810 | 52 | 13 |
| 48 | 12 | 9·787395 | 271 | 0·212605 | 9·889682 | 435 | 0·110318 | 0·102288 | 163 | 9·897712 | 48 | 12 |
| 49 | 16 | 9·787557 | 271 | 0·212443 | 9·889943 | 435 | 0·110057 | 0·102386 | 163 | 9·897614 | 44 | 11 |
| 50 | 20 | 9·787720 | 271 | 0·212280 | 9·890204 | 435 | 0·109796 | 0·102484 | 163 | 9·897516 | 40 | 10 |
| 51 | 24 | 9·787883 | 271 | 0·212117 | 9·890465 | 434 | 0·109535 | 0·102582 | 164 | 9·897418 | 36 | 9 |
| 52 | 28 | 9·788045 | 271 | 0·211955 | 9·890725 | 434 | 0·109275 | 0·102680 | 164 | 9·897320 | 32 | 8 |
| 53 | 32 | 9·788208 | 271 | 0·211792 | 9·890986 | 434 | 0·109014 | 0·102778 | 164 | 9·897222 | 28 | 7 |
| 54 | 36 | 9·788370 | 270 | 0·211630 | 9·891247 | 434 | 0·108753 | 0·102877 | 164 | 9·897123 | 24 | 6 |
| 55 | 40 | 9·788532 | 270 | 0·211468 | 9·891507 | 434 | 0·108493 | 0·102975 | 164 | 9·897025 | 20 | 5 |
| 56 | 44 | 9·788694 | 270 | 0·211306 | 9·891768 | 434 | 0·108232 | 0·103074 | 164 | 9·896926 | 16 | 4 |
| 57 | 48 | 9·788856 | 270 | 0·211144 | 9·892028 | 434 | 0·107972 | 0·103172 | 164 | 9·896828 | 12 | 3 |
| 58 | 52 | 9·789018 | 270 | 0·210982 | 9·892289 | 434 | 0·107711 | 0·103271 | 164 | 9·896729 | 8 | 2 |
| 59 | 56 | 9·789180 | 270 | 0·210820 | 9·892549 | 434 | 0·107451 | 0·103369 | 164 | 9·896631 | 4 | 1 |
| 60 | 32 | 9·789342 | 270 | 0·210658 | 9·892810 | 434 | 0·107190 | 0·103468 | 164 | 9·896532 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

127° 52°=3h 28m 52°

## LOG. SINES, COSINES, &c.

38° 38°=2h 32m 141°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9 789342 | 269 | 0·210658 | 9 892810 | 434 | 0·107190 | 0·103468 | 164 | 9 896532 | 28 | 60 |
| 1 | 4 | 9 789504 | 269 | 0·210496 | 9 893070 | 434 | 0·106930 | 0·103567 | 165 | 9 896433 | 56 | 59 |
| 2 | 8 | 9 789665 | 269 | 0·210335 | 9 893331 | 434 | 0·106669 | 0·103665 | 165 | 9 896335 | 52 | 58 |
| 3 | 12 | 9 789827 | 269 | 0·210173 | 9 893591 | 434 | 0·106409 | 0 103764 | 165 | 9 896236 | 48 | 57 |
| 4 | 16 | 9 789988 | 269 | 0·210012 | 9 893851 | 434 | 0·106149 | 0·103863 | 165 | 9 896137 | 44 | 56 |
| 5 | 20 | 9·790149 | 269 | 0·209851 | 9 894111 | 434 | 0·105889 | 0 103962 | 165 | 9·896038 | 40 | 55 |
| 6 | 24 | 9 790310 | 268 | 0·209690 | 9 894372 | 434 | 0·105628 | 0·104061 | 165 | 9 895939 | 36 | 54 |
| 7 | 28 | 9 790471 | 268 | 0·209529 | 9 894632 | 433 | 0·105368 | 0·104160 | 165 | 9 895840 | 32 | 53 |
| 8 | 32 | 9·790632 | 268 | 0·209368 | 9 894892 | 433 | 0·105108 | 0·104259 | 165 | 9 895741 | 28 | 52 |
| 9 | 36 | 9 790793 | 268 | 0·209207 | 9 895152 | 433 | 0·104848 | 0·104359 | 165 | 9 895641 | 24 | 51 |
| 10 | 40 | 9 790954 | 268 | 0·209046 | 9·895412 | 433 | 0·104588 | 0·104458 | 165 | 9 895542 | 20 | 50 |
| 11 | 44 | 9 791115 | 268 | 0·208885 | 9 895672 | 433 | 0·104328 | 0 104557 | 166 | 9 895443 | 16 | 49 |
| 12 | 48 | 9 791275 | 267 | 0·208725 | 9 895932 | 433 | 0·104068 | 0·104657 | 166 | 9 895343 | 12 | 48 |
| 13 | 52 | 9·791436 | 267 | 0·208564 | 9 896192 | 433 | 0·103808 | 0·104756 | 166 | 9 895244 | 8 | 47 |
| 14 | 56 | 9·791596 | 267 | 0·208404 | 9 896452 | 433 | 0·103548 | 0·104855 | 166 | 9 895145 | 4 | 46 |
| 15 | **33** | 9·791757 | 267 | 0·208243 | 9 896712 | 433 | 0·103288 | 0·104955 | 166 | 9 895045 | **27** | 45 |
| 16 | 4 | 9 791917 | 267 | 0 208083 | 9 896971 | 433 | 0·103029 | 0·105055 | 166 | 9·894945 | 56 | 44 |
| 17 | 8 | 9·792077 | 267 | 0·207923 | 9·897231 | 433 | 0·102769 | 0·105154 | 166 | 9 894846 | 52 | 43 |
| 18 | 12 | 9 792237 | 266 | 0 207763 | 9 897491 | 433 | 0·102509 | 0·105254 | 166 | 9 894746 | 48 | 42 |
| 19 | 16 | 9 792397 | 266 | 0·207603 | 9 897751 | 433 | 0·102249 | 0·105354 | 166 | 9 894646 | 44 | 41 |
| 20 | 20 | 9 792557 | 266 | 0·207443 | 9 898010 | 433 | 0·101990 | 0·105454 | 166 | 9 894546 | 40 | 40 |
| 21 | 24 | 9·792716 | 266 | 0 207284 | 9 898270 | 433 | 0 101730 | 0·105554 | 167 | 9 894446 | 36 | 39 |
| 22 | 28 | 9·792876 | 266 | 0·207124 | 9 898530 | 433 | 0·101470 | 0·105654 | 167 | 9·894346 | 32 | 38 |
| 23 | 32 | 9 793035 | 266 | 0·206965 | 9 898789 | 433 | 0·101211 | 0·105754 | 167 | 9 894246 | 28 | 37 |
| 24 | 36 | 9 793195 | 265 | 0·206805 | 9·899049 | 432 | 0·100951 | 0·105854 | 167 | 9 894146 | 24 | 36 |
| 25 | 40 | 9 793354 | 265 | 0·206646 | 9 899308 | 432 | 0·100692 | 0·105954 | 167 | 9 894046 | 20 | 35 |
| 26 | 44 | 9 793514 | 265 | 0·206486 | 9 899568 | 432 | 0·100432 | 0·106054 | 167 | 9·893946 | 16 | 34 |
| 27 | 48 | 9 793673 | 265 | 0·206327 | 9 899827 | 432 | 0·100173 | 0·106154 | 167 | 9 893846 | 12 | 33 |
| 28 | 52 | 9 793832 | 265 | 0·206168 | 9 900087 | 432 | 0·099913 | 0·106255 | 167 | 9 893745 | 8 | 32 |
| 29 | 56 | 9·793991 | 265 | 0·206009 | 9 900346 | 432 | 0 099654 | 0 106355 | 167 | 9·893645 | 4 | 31 |
| 30 | **34** | 9 794150 | 264 | 0 205850 | 9 900605 | 432 | 0·099395 | 0·106456 | 167 | 9·893544 | **26** | 30 |
| 31 | 4 | 9 794308 | 264 | 0·205692 | 9 900864 | 432 | 0·099136 | 0·106556 | 168 | 9 893444 | 56 | 29 |
| 32 | 8 | 9 794467 | 264 | 0·205533 | 9 901124 | 432 | 0 098876 | 0·106657 | 168 | 9 893343 | 52 | 28 |
| 33 | 12 | 9 794626 | 264 | 0·205374 | 9 901383 | 432 | 0 098617 | 0·106757 | 168 | 9·893243 | 48 | 27 |
| 34 | 16 | 9 794784 | 264 | 0·205216 | 9 901642 | 432 | 0·098358 | 0 106858 | 168 | 9·893142 | 44 | 26 |
| 35 | 20 | 9 794942 | 264 | 0·205058 | 9 901901 | 432 | 0·098099 | 0·106959 | 168 | 9 893041 | 40 | 25 |
| 36 | 24 | 9 795101 | 264 | 0·204899 | 9 902160 | 432 | 0 097840 | 0·107060 | 168 | 9 892940 | 36 | 24 |
| 37 | 28 | 9 795259 | 263 | 0·204741 | 9 902420 | 432 | 0·097580 | 0·107161 | 168 | 9·892839 | 32 | 23 |
| 38 | 32 | 9·795417 | 263 | 0·204583 | 9 902679 | 432 | 0·097321 | 0·107261 | 168 | 9 892739 | 28 | 22 |
| 39 | 36 | 9·795575 | 263 | 0·204425 | 9 902938 | 432 | 0·097062 | 0·107362 | 168 | 9 892638 | 24 | 21 |
| 40 | 40 | 9 795733 | 263 | 0·204267 | 9 903197 | 431 | 0·096803 | 0·107464 | 168 | 9 892536 | 20 | 20 |
| 41 | 44 | 9 795891 | 263 | 0 204109 | 9 903456 | 431 | 0·096544 | 0·107565 | 169 | 9·892435 | 16 | 19 |
| 42 | 48 | 9 796049 | 263 | 0·203951 | 9 903714 | 431 | 0·096286 | 0·107666 | 169 | 9·892334 | 12 | 18 |
| 43 | 52 | 9 796206 | 263 | 0·203794 | 9 903973 | 431 | 0·096027 | 0·107767 | 169 | 9 892233 | 8 | 17 |
| 44 | 56 | 9 796364 | 262 | 0·203636 | 9 904232 | 431 | 0·095768 | 0·107868 | 169 | 9 892132 | 4 | 16 |
| 45 | **35** | 9·796521 | 262 | 0·203479 | 9·904491 | 431 | 0·095509 | 0·107970 | 169 | 9 892030 | **25** | 15 |
| 46 | 4 | 9 796679 | 262 | 0·203321 | 9 904750 | 431 | 0·095250 | 0·108071 | 169 | 9 891929 | 56 | 14 |
| 47 | 8 | 9·796836 | 262 | 0·203164 | 9 905008 | 431 | 0·094992 | 0·108173 | 169 | 9 891827 | 52 | 13 |
| 48 | 12 | 9·796993 | 262 | 0·203007 | 9 905267 | 431 | 0·094733 | 0·108274 | 169 | 9·891726 | 48 | 12 |
| 49 | 16 | 9·797150 | 261 | 0·202850 | 9·905526 | 431 | 0·094474 | 0·108376 | 169 | 9·891624 | 44 | 11 |
| 50 | 20 | 9·797307 | 261 | 0·202693 | 9 905785 | 431 | 0·094215 | 0·108477 | 170 | 9·891523 | 40 | 10 |
| 51 | 24 | 9·797464 | 261 | 0·202536 | 9 906043 | 431 | 0·093957 | 0·108579 | 170 | 9·891421 | 36 | 9 |
| 52 | 28 | 9·797621 | 261 | 0·202379 | 9 906302 | 431 | 0·093698 | 0·108681 | 170 | 9·891319 | 32 | 8 |
| 53 | 32 | 9 797777 | 261 | 0·202223 | 9 906560 | 431 | 0·093440 | 0·108783 | 170 | 9 891217 | 28 | 7 |
| 54 | 36 | 9·797934 | 261 | 0·202066 | 9 906819 | 431 | 0·093181 | 0·108885 | 170 | 9·891115 | 24 | 6 |
| 55 | 40 | 9·798091 | 261 | 0·201909 | 9 907077 | 431 | 0·092923 | 0·108987 | 170 | 9·891013 | 20 | 5 |
| 56 | 44 | 9·798247 | 261 | 0·201753 | 9 907336 | 431 | 0·092664 | 0·109089 | 170 | 9·890911 | 16 | 4 |
| 57 | 48 | 9 798403 | 260 | 0·201597 | 9·907594 | 431 | 0·092406 | 0·109191 | 170 | 9·890809 | 12 | 3 |
| 58 | 52 | 9·798560 | 260 | 0·201440 | 9 907853 | 431 | 0·092147 | 0·109293 | 170 | 9·890707 | 8 | 2 |
| 59 | 56 | 9·798716 | 260 | 0·201284 | 9 908111 | 430 | 0·091889 | 0·109395 | 170 | 9·890605 | 4 | 1 |
| 60 | **36** | 9 798872 | | 0·201128 | 9·908369 | | 0·091631 | 0·109497 | | 9·890503 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

128° 51°=3h 24m 51°

## LOG. SINES, COSINES, &c.

39° 39°=2h 36m 140°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·798872 | 260 | 0·201128 | 9·908369 | 430 | 0·091631 | 0·109497 | 170 | 9·890503 | **24** | 60 |
| 1 | 4 | 9·799028 | 260 | 0·200972 | 9 908628 | 430 | 0·091372 | 0·109600 | 171 | 9 890400 | 56 | 59 |
| 2 | 8 | 9·799184 | 260 | 0·200816 | 9 908886 | 430 | 0·091114 | 0·109702 | 171 | 9 890298 | 52 | 58 |
| 3 | 12 | 9·799339 | 259 | 0·200661 | 9·909144 | 430 | 0·090856 | 0·109805 | 171 | 9 890195 | 48 | 57 |
| 4 | 16 | 9·799495 | 259 | 0·200505 | 9·909402 | 430 | 0·090598 | 0·109907 | 171 | 9·890093 | 44 | 56 |
| 5 | 20 | 9·799651 | 259 | 0·200349 | 9·909660 | 430 | 0·090340 | 0·110010 | 171 | 9·889990 | 40 | 55 |
| 6 | 24 | 9·799806 | 259 | 0·200194 | 9 909918 | 430 | 0·090082 | 0·110112 | 171 | 9 889888 | 36 | 54 |
| 7 | 28 | 9·799962 | 259 | 0·200038 | 9·910177 | 430 | 0·089823 | 0·110215 | 171 | 9 889785 | 32 | 53 |
| 8 | 32 | 9·800117 | 259 | 0·199883 | 9·910435 | 430 | 0·089565 | 0·110318 | 171 | 9 889682 | 28 | 52 |
| 9 | 36 | 9·800272 | 258 | 0·199728 | 9 910693 | 430 | 0·089307 | 0·110421 | 171 | 9 889579 | 24 | 51 |
| 10 | 40 | 9·800427 | 258 | 0·199573 | 9·910951 | 430 | 0·089049 | 0·110523 | 171 | 9·889477 | 20 | 50 |
| 11 | 44 | 9·800582 | 258 | 0·199418 | 9·911209 | 430 | 0·088791 | 0·110626 | 172 | 9 889374 | 16 | 49 |
| 12 | 48 | 9·800737 | 258 | 0·199263 | 9 911467 | 430 | 0·088533 | 0·110729 | 172 | 9·889271 | 12 | 48 |
| 13 | 52 | 9·800892 | 258 | 0·199108 | 9·911725 | 430 | 0·088275 | 0·110832 | 172 | 9 889168 | 8 | 47 |
| 14 | 56 | 9·801047 | 258 | 0·198953 | 9 911982 | 430 | 0·088018 | 0·110936 | 172 | 9·889064 | 4 | 46 |
| 15 | **37** | 9·801201 | 258 | 0·198799 | 9 912240 | 430 | 0·087760 | 0·111039 | 172 | 9·888961 | **23** | 45 |
| 16 | 4 | 9·801356 | 257 | 0·198644 | 9 912498 | 430 | 0·087502 | 0·111142 | 172 | 9·888858 | 56 | 44 |
| 17 | 8 | 9·801511 | 257 | 0·198489 | 9·912756 | 430 | 0·087244 | 0·111245 | 172 | 9·888755 | 52 | 43 |
| 18 | 12 | 9·801665 | 257 | 0·198335 | 9·913014 | 430 | 0·086986 | 0·111349 | 172 | 9 888651 | 48 | 42 |
| 19 | 16 | 9·801819 | 257 | 0·198181 | 9 913271 | 429 | 0·086729 | 0·111452 | 172 | 9 888548 | 44 | 41 |
| 20 | 20 | 9·801973 | 257 | 0·198027 | 9·913529 | 429 | 0·086471 | 0·111556 | 172 | 9 888444 | 40 | 40 |
| 21 | 24 | 9·802128 | 257 | 0·197872 | 9·913787 | 429 | 0·086213 | 0·111659 | 173 | 9·888341 | 36 | 39 |
| 22 | 28 | 9·802282 | 256 | 0·197718 | 9 914044 | 429 | 0·085956 | 0·111763 | 173 | 9·888237 | 32 | 38 |
| 23 | 32 | 9·802436 | 256 | 0·197564 | 9·914302 | 429 | 0·085698 | 0·111866 | 173 | 9 888134 | 28 | 37 |
| 24 | 36 | 9·802589 | 256 | 0·197411 | 9·914560 | 429 | 0·085440 | 0·111970 | 173 | 9 888030 | 24 | 36 |
| 25 | 40 | 9·802743 | 256 | 0·197257 | 9 914817 | 429 | 0·085183 | 0·112074 | 173 | 9·887926 | 20 | 35 |
| 26 | 44 | 9·802897 | 256 | 0·197103 | 9·915075 | 429 | 0·084925 | 0·112178 | 173 | 9·887822 | 16 | 34 |
| 27 | 48 | 9·803050 | 256 | 0·196950 | 9·915332 | 429 | 0·084668 | 0·112282 | 173 | 9·887718 | 12 | 33 |
| 28 | 52 | 9·803204 | 256 | 0·196796 | 9·915590 | 429 | 0·084410 | 0·112386 | 173 | 9 887614 | 8 | 32 |
| 29 | 56 | 9·803357 | 255 | 0·196643 | 9·915847 | 429 | 0·084153 | 0·112490 | 173 | 9·887510 | 4 | 31 |
| 30 | **38** | 9·803511 | 255 | 0·196489 | 9·916104 | 429 | 0·083896 | 0·112594 | 173 | 9·887406 | **22** | 30 |
| 31 | 4 | 9·803664 | 255 | 0·196336 | 9·916362 | 429 | 0·083638 | 0·112698 | 174 | 9·887302 | 56 | 29 |
| 32 | 8 | 9·803817 | 255 | 0·196183 | 9·916619 | 429 | 0·083381 | 0·112802 | 174 | 9·887198 | 52 | 28 |
| 33 | 12 | 9·803970 | 255 | 0·196030 | 9·916877 | 429 | 0·083123 | 0·112907 | 174 | 9 887093 | 48 | 27 |
| 34 | 16 | 9·804123 | 255 | 0·195877 | 9·917134 | 429 | 0·082866 | 0·113011 | 174 | 9·886989 | 44 | 26 |
| 35 | 20 | 9·804276 | 254 | 0·195724 | 9·917391 | 429 | 0·082609 | 0·113115 | 174 | 9·886885 | 40 | 25 |
| 36 | 24 | 9·804428 | 254 | 0·195572 | 9 917648 | 429 | 0·082352 | 0·113220 | 174 | 9·886780 | 36 | 24 |
| 37 | 28 | 9·804581 | 254 | 0·195419 | 9·917906 | 429 | 0·082094 | 0·113324 | 174 | 9·886676 | 32 | 23 |
| 38 | 32 | 9·804734 | 254 | 0·195266 | 9·918163 | 429 | 0·081837 | 0·113429 | 174 | 9·886571 | 28 | 22 |
| 39 | 36 | 9·804886 | 254 | 0·195114 | 9·918420 | 428 | 0·081580 | 0·113534 | 174 | 9·886466 | 24 | 21 |
| 40 | 40 | 9·805039 | 254 | 0·194961 | 9·918677 | 428 | 0·081323 | 0·113638 | 174 | 9·886362 | 20 | 20 |
| 41 | 44 | 9·805191 | 254 | 0·194809 | 9·918934 | 428 | 0·081066 | 0·113743 | 175 | 9·886257 | 16 | 19 |
| 42 | 48 | 9·805343 | 253 | 0·194657 | 9·919191 | 428 | 0·080809 | 0·113848 | 175 | 9·886152 | 12 | 18 |
| 43 | 52 | 9·805495 | 253 | 0·194505 | 9·919448 | 428 | 0·080552 | 0·113953 | 175 | 9 886047 | 8 | 17 |
| 44 | 56 | 9·805647 | 253 | 0·194353 | 9·919705 | 428 | 0·080295 | 0·114058 | 175 | 9 885942 | 4 | 16 |
| 45 | **39** | 9·805799 | 253 | 0·194201 | 9·919962 | 428 | 0·080038 | 0·114163 | 175 | 9·885837 | **21** | 15 |
| 46 | 4 | 9·805951 | 253 | 0·194049 | 9·920219 | 428 | 0·079781 | 0·114268 | 175 | 9·885732 | 56 | 14 |
| 47 | 8 | 9·806103 | 253 | 0·193897 | 9·920476 | 428 | 0·079524 | 0·114373 | 175 | 9·885627 | 52 | 13 |
| 48 | 12 | 9·806254 | 253 | 0·193746 | 9·920733 | 428 | 0·079267 | 0·114478 | 175 | 9·885522 | 48 | 12 |
| 49 | 16 | 9·806406 | 252 | 0·193594 | 9·920990 | 428 | 0·079010 | 0·114584 | 175 | 9·885416 | 44 | 11 |
| 50 | 20 | 9·806557 | 252 | 0·193443 | 9·921247 | 428 | 0·078753 | 0·114689 | 176 | 9·8853 11 | 40 | 10 |
| 51 | 24 | 9·806709 | 252 | 0·193291 | 9·921503 | 428 | 0·078497 | 0·114795 | 176 | 9·885205 | 36 | 9 |
| 52 | 28 | 9·806860 | 252 | 0·193140 | 9·921760 | 428 | 0·078240 | 0·114900 | 176 | 9·885100 | 32 | 8 |
| 53 | 32 | 9·807011 | 252 | 0·192989 | 9·922017 | 428 | 0·077983 | 0·115006 | 176 | 9·884994 | 28 | 7 |
| 54 | 36 | 9·807163 | 252 | 0·192837 | 9·922274 | 428 | 0·077726 | 0·115111 | 176 | 9·884889 | 24 | 6 |
| 55 | 40 | 9·807314 | 252 | 0·192686 | 9·922530 | 428 | 0·077470 | 0·115217 | 176 | 9·884783 | 20 | 5 |
| 56 | 44 | 9·807465 | 251 | 0·192535 | 9·922787 | 428 | 0·077213 | 0·115323 | 176 | 9·884677 | 16 | 4 |
| 57 | 48 | 9·807615 | 251 | 0·192385 | 9·923044 | 428 | 0·076956 | 0·115428 | 176 | 9·884572 | 12 | 3 |
| 58 | 52 | 9·807766 | 251 | 0·192234 | 9·923300 | 428 | 0·076700 | 0·115534 | 176 | 9·884466 | 8 | 2 |
| 59 | 56 | 9·807917 | 251 | 0·192083 | 9·923557 | 428 | 0·076443 | 0·115640 | 176 | 9·884360 | 4 | 1 |
| 60 | **40** | 9·808067 | 251 | 0·191933 | 9·923814 | 427 | 0·076186 | 0·115746 | 176 | 9·884254 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

129° 50°=3h 20m 50°

LOG. SINES, COSINES, &c.

| 40° | | | | | 40° = 2h 40m | | | | | | 139° |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ′ | M. S. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | ′ |
| 0 | 0 | 9·808067 | 251 | 0·191933 | 9·923814 | 427 | 0·076186 | 0·115746 | 177 | 9·884254 | 60 |
| 1 | 4 | 9·808218 | 251 | 0·191782 | 9·924070 | 427 | 0·075930 | 0·115852 | 177 | 9·884148 | 59 |
| 2 | 8 | 9·808368 | 251 | 0·191632 | 9·924327 | 427 | 0·075673 | 0·115958 | 177 | 9·884042 | 58 |
| 3 | 12 | 9·808519 | 250 | 0·191481 | 9·924583 | 427 | 0·075417 | 0·116064 | 177 | 9·883936 | 57 |
| 4 | 16 | 9·808669 | 250 | 0·191331 | 9·924840 | 427 | 0·075160 | 0·116171 | 177 | 9·883829 | 56 |
| 5 | 20 | 9·808819 | 250 | 0·191181 | 9·925096 | 427 | 0·074904 | 0·116277 | 177 | 9·883723 | 55 |
| 6 | 24 | 9·808969 | 250 | 0·191031 | 9·925352 | 427 | 0·074648 | 0·116383 | 177 | 9·883617 | 54 |
| 7 | 28 | 9·809119 | 250 | 0·190881 | 9·925609 | 427 | 0·074391 | 0·116490 | 177 | 9·883510 | 53 |
| 8 | 32 | 9·809269 | 250 | 0·190731 | 9·925865 | 427 | 0·074135 | 0·116596 | 177 | 9·883404 | 52 |
| 9 | 36 | 9·809419 | 249 | 0·190581 | 9·926122 | 427 | 0·073878 | 0·116703 | 177 | 9·883297 | 51 |
| 10 | 40 | 9·809569 | 249 | 0·190431 | 9·926378 | 427 | 0·073622 | 0·116809 | 178 | 9·883191 | 50 |
| 11 | 44 | 9·809718 | 249 | 0·190282 | 9·926634 | 427 | 0·073366 | 0·116916 | 178 | 9·883084 | 49 |
| 12 | 48 | 9·809868 | 249 | 0·190132 | 9·926890 | 427 | 0·073110 | 0·117023 | 178 | 9·882977 | 48 |
| 13 | 52 | 9·810017 | 249 | 0·189983 | 9·927147 | 427 | 0·072853 | 0·117129 | 178 | 9·882871 | 47 |
| 14 | 56 | 9·810167 | 249 | 0·189833 | 9·927403 | 427 | 0·072597 | 0·117236 | 178 | 9·882764 | 46 |
| 15 | **41** | 9·810316 | 248 | 0·189684 | 9·927659 | 427 | 0·072341 | 0·117343 | 178 | 9·882657 | **19** 45 |
| 16 | 4 | 9·810465 | 248 | 0·189535 | 9·927915 | 427 | 0·072085 | 0·117450 | 178 | 9·882550 | 56 44 |
| 17 | 8 | 9·810614 | 248 | 0·189386 | 9·928171 | 427 | 0·071829 | 0·117557 | 178 | 9·882443 | 52 43 |
| 18 | 12 | 9·810763 | 248 | 0·189237 | 9·928427 | 427 | 0·071573 | 0·117664 | 178 | 9·882336 | 48 42 |
| 19 | 16 | 9·810912 | 248 | 0·189088 | 9·928684 | 427 | 0·071316 | 0·117771 | 179 | 9·882229 | 44 41 |
| 20 | 20 | 9·811061 | 248 | 0·188939 | 9·928940 | 427 | 0·071060 | 0·117879 | 179 | 9·882121 | 40 40 |
| 21 | 24 | 9·811210 | 248 | 0·188790 | 9·929196 | 427 | 0·070804 | 0·117986 | 179 | 9·882014 | 36 39 |
| 22 | 28 | 9·811358 | 247 | 0·188642 | 9·929452 | 427 | 0·070548 | 0·118093 | 179 | 9·881907 | 32 38 |
| 23 | 32 | 9·811507 | 247 | 0·188493 | 9·929708 | 427 | 0·070292 | 0·118201 | 179 | 9·881799 | 28 37 |
| 24 | 36 | 9·811655 | 247 | 0·188345 | 9·929964 | 427 | 0·070036 | 0·118308 | 179 | 9·881692 | 24 36 |
| 25 | 40 | 9·811804 | 247 | 0·188196 | 9·930220 | 426 | 0·069780 | 0·118416 | 179 | 9·881584 | 20 35 |
| 26 | 44 | 9·811952 | 247 | 0·188048 | 9·930475 | 426 | 0·069525 | 0·118523 | 179 | 9·881477 | 16 34 |
| 27 | 48 | 9·812100 | 247 | 0·187900 | 9·930731 | 426 | 0·069269 | 0·118631 | 179 | 9·881369 | 12 33 |
| 28 | 52 | 9·812248 | 247 | 0·187752 | 9·930987 | 426 | 0·069013 | 0·118739 | 179 | 9·881261 | 8 32 |
| 29 | 56 | 9·812396 | 246 | 0·187604 | 9·931243 | 426 | 0·068757 | 0·118847 | 180 | 9·881153 | 4 31 |
| 30 | **42** | 9·812544 | 246 | 0·187456 | 9·931499 | 426 | 0·068501 | 0·118954 | 180 | 9·881046 | **18** 30 |
| 31 | 4 | 9·812692 | 246 | 0·187308 | 9·931755 | 426 | 0·068245 | 0·119062 | 180 | 9·880938 | 56 29 |
| 32 | 8 | 9·812840 | 246 | 0·187160 | 9·932010 | 426 | 0·067990 | 0·119170 | 180 | 9·880830 | 52 28 |
| 33 | 12 | 9·812988 | 246 | 0·187012 | 9·932266 | 426 | 0·067734 | 0·119278 | 180 | 9·880722 | 48 27 |
| 34 | 16 | 9·813135 | 246 | 0·186865 | 9·932522 | 426 | 0·067478 | 0·119387 | 180 | 9·880613 | 44 26 |
| 35 | 20 | 9·813283 | 246 | 0·186717 | 9·932778 | 426 | 0·067222 | 0·119495 | 180 | 9·880505 | 40 25 |
| 36 | 24 | 9·813430 | 245 | 0·186570 | 9·933033 | 426 | 0·066967 | 0·119603 | 180 | 9·880397 | 36 24 |
| 37 | 28 | 9·813578 | 245 | 0·186422 | 9·933289 | 426 | 0·066711 | 0·119711 | 181 | 9·880289 | 32 23 |
| 38 | 32 | 9·813725 | 245 | 0·186275 | 9·933545 | 426 | 0·066455 | 0·119820 | 181 | 9·880180 | 28 22 |
| 39 | 36 | 9·813872 | 245 | 0·186128 | 9·933800 | 426 | 0·066200 | 0·119928 | 181 | 9·880072 | 24 21 |
| 40 | 40 | 9·814019 | 245 | 0·185981 | 9·934056 | 426 | 0·065944 | 0·120037 | 181 | 9·879963 | 20 20 |
| 41 | 44 | 9·814166 | 245 | 0·185834 | 9·934311 | 426 | 0·065689 | 0·120145 | 181 | 9·879855 | 16 19 |
| 42 | 48 | 9·814313 | 245 | 0·185687 | 9·934567 | 426 | 0·065433 | 0·120254 | 181 | 9·879746 | 12 18 |
| 43 | 52 | 9·814460 | 244 | 0·185540 | 9·934822 | 426 | 0·065178 | 0·120363 | 181 | 9·879637 | 8 17 |
| 44 | 56 | 9·814607 | 244 | 0·185393 | 9·935078 | 426 | 0·064922 | 0·120471 | 181 | 9·879529 | 4 16 |
| 45 | **43** | 9·814753 | 244 | 0·185247 | 9·935333 | 426 | 0·064667 | 0·120580 | 181 | 9·879420 | **17** 15 |
| 46 | 4 | 9·814900 | 244 | 0·185100 | 9·935589 | 426 | 0·064411 | 0·120689 | 181 | 9·879311 | 56 14 |
| 47 | 8 | 9·815046 | 244 | 0·184954 | 9·935844 | 426 | 0·064156 | 0·120798 | 182 | 9·879202 | 52 13 |
| 48 | 12 | 9·815193 | 244 | 0·184807 | 9·936100 | 426 | 0·063900 | 0·120907 | 182 | 9·879093 | 48 12 |
| 49 | 16 | 9·815339 | 244 | 0·184661 | 9·936355 | 426 | 0·063645 | 0·121016 | 182 | 9·878984 | 44 11 |
| 50 | 20 | 9·815485 | 243 | 0·184515 | 9·936611 | 426 | 0·063389 | 0·121125 | 182 | 9·878875 | 40 10 |
| 51 | 24 | 9·815632 | 243 | 0·184368 | 9·936866 | 425 | 0·063134 | 0·121234 | 182 | 9·878766 | 36 9 |
| 52 | 28 | 9·815778 | 243 | 0·184222 | 9·937121 | 425 | 0·062879 | 0·121344 | 182 | 9·878656 | 32 8 |
| 53 | 32 | 9·815924 | 243 | 0·184076 | 9·937377 | 425 | 0·062623 | 0·121453 | 182 | 9·878547 | 28 7 |
| 54 | 36 | 9·816069 | 243 | 0·183931 | 9·937632 | 425 | 0·062368 | 0·121562 | 182 | 9·878438 | 24 6 |
| 55 | 40 | 9·816215 | 243 | 0·183785 | 9·937887 | 425 | 0·062113 | 0·121672 | 182 | 9·878328 | 20 5 |
| 56 | 44 | 9·816361 | 243 | 0·183639 | 9·938142 | 425 | 0·061858 | 0·121781 | 183 | 9·878219 | 16 4 |
| 57 | 48 | 9·816507 | 242 | 0·183493 | 9·938398 | 425 | 0·061602 | 0·121891 | 183 | 9·878109 | 12 3 |
| 58 | 52 | 9·816652 | 242 | 0·183348 | 9·938653 | 425 | 0·061347 | 0·122001 | 183 | 9·877999 | 8 2 |
| 59 | 56 | 9·816798 | 242 | 0·183202 | 9·938908 | 425 | 0·061092 | 0·122110 | 183 | 9·877890 | 4 1 |
| 60 | **44** | 9·816943 | | 0·183057 | 9·939163 | | 0·060837 | 0·122220 | | 9·877780 | 0 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. ′ |
| 130° | | | | | 49° = 3h 16m | | | | | | 49° |

LOG. SINES, COSINES, &c.

41° 41°=2h 44m 138°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·816943 | 242 | 0·183057 | 9 939163 | 425 | 0·060837 | 0·122220 | 183 | 9 877780 | **16** | 60 |
| 1 | 4 | 9·817088 | 242 | 0·182912 | 9 939418 | 425 | 0 060582 | 0 122330 | 183 | 9 877670 | 56 | 59 |
| 2 | 8 | 9·817233 | 242 | 0·182767 | 9 939673 | 425 | 0 060327 | 0 122440 | 183 | 9 877560 | 52 | 58 |
| 3 | 12 | 9·817379 | 242 | 0·182621 | 9 939928 | 425 | 0 060072 | 0 122550 | 183 | 9 877450 | 48 | 57 |
| 4 | 16 | 9·817524 | 241 | 0·182476 | 9 940183 | 425 | 0 059817 | 0·122660 | 183 | 9 877340 | 44 | 56 |
| 5 | 20 | 9·817668 | 241 | 0·182332 | 9 940439 | 425 | 0·059561 | 0 122770 | 184 | 9 877230 | 40 | 55 |
| 6 | 24 | 9·817813 | 241 | 0·182187 | 9 940694 | 425 | 0 059306 | 0 122880 | 184 | 9 877120 | 36 | 54 |
| 7 | 28 | 9·817958 | 241 | 0·182042 | 9 940949 | 425 | 0 059051 | 0 122990 | 184 | 9 877010 | 32 | 53 |
| 8 | 32 | 9·818103 | 241 | 0·181897 | 9 941204 | 425 | 0 058796 | 0 123101 | 184 | 9 876899 | 28 | 52 |
| 9 | 36 | 9·818247 | 241 | 0·181753 | 9 941459 | 425 | 0 058541 | 0 123211 | 184 | 9 876789 | 24 | 51 |
| 10 | 40 | 9·818392 | 241 | 0·181608 | 9 941713 | 425 | 0 058287 | 0·123322 | 184 | 9 876678 | 20 | 50 |
| 11 | 44 | 9·818536 | 240 | 0·181464 | 9 941968 | 425 | 0 058032 | 0·123432 | 184 | 9 876568 | 16 | 49 |
| 12 | 48 | 9·818681 | 240 | 0·181319 | 9 942223 | 425 | 0·057777 | 0·123543 | 184 | 9 876457 | 12 | 48 |
| 13 | 52 | 9 818825 | 240 | 0·181175 | 9 942478 | 425 | 0 057522 | 0 123653 | 184 | 9 876347 | 8 | 47 |
| 14 | 56 | 9·818969 | 240 | 0·181031 | 9 942733 | 425 | 0 057267 | 0 123764 | 185 | 9 876236 | 4 | 46 |
| 15 | **45** | 9·819113 | 240 | 0·180887 | 9 942988 | 425 | 0 057012 | 0·123875 | 185 | 9 876125 | **15** | 45 |
| 16 | 4 | 9·819257 | 240 | 0·180743 | 9 943243 | 425 | 0 056757 | 0 123986 | 185 | 9·876014 | 56 | 44 |
| 17 | 8 | 9·819401 | 240 | 0·180599 | 9 943498 | 425 | 0 056502 | 0 124096 | 185 | 9 875904 | 52 | 43 |
| 18 | 12 | 9·819545 | 240 | 0·180455 | 9 943752 | 425 | 0 056248 | 0 124207 | 185 | 9 875793 | 48 | 42 |
| 19 | 16 | 9·819689 | 239 | 0·180311 | 9 944007 | 425 | 0 055993 | 0 124318 | 185 | 9 875682 | 44 | 41 |
| 20 | 20 | 9·819832 | 239 | 0·180168 | 9 944262 | 425 | 0·055738 | 0·124429 | 185 | 9 875571 | 40 | 40 |
| 21 | 24 | 9·819976 | 239 | 0·180024 | 9 944517 | 425 | 0 055483 | 0·124541 | 185 | 9·875459 | 36 | 39 |
| 22 | 28 | 9·820120 | 239 | 0·179880 | 9 944771 | 424 | 0·055229 | 0·124652 | 185 | 9 875348 | 32 | 38 |
| 23 | 32 | 9·820263 | 239 | 0·179737 | 9·945026 | 424 | 0·054974 | 0·124763 | 185 | 9 875237 | 28 | 37 |
| 24 | 36 | 9·820406 | 239 | 0·179594 | 9 945281 | 424 | 0·054719 | 0·124874 | 186 | 9 875126 | 24 | 36 |
| 25 | 40 | 9·820550 | 238 | 0·179450 | 9 945535 | 424 | 0·054465 | 0·124986 | 186 | 9 875014 | 20 | 35 |
| 26 | 44 | 9·820693 | 238 | 0·179307 | 9 945790 | 424 | 0·054210 | 0·125097 | 186 | 9 874903 | 16 | 34 |
| 27 | 48 | 9·820836 | 238 | 0·179164 | 9 946045 | 424 | 0·053955 | 0·125209 | 186 | 9·874791 | 12 | 33 |
| 28 | 52 | 9·820979 | 238 | 0·179021 | 9 946299 | 424 | 0·053701 | 0·125320 | 186 | 9 874680 | 8 | 32 |
| 29 | 56 | 9·821122 | 238 | 0·178878 | 9 946554 | 424 | 0·053446 | 0·125432 | 186 | 9·874568 | 4 | 31 |
| 30 | **46** | 9·821265 | 238 | 0·178735 | 9·946808 | 424 | 0·053192 | 0·125544 | 186 | 9·874456 | **14** | 30 |
| 31 | 4 | 9·821407 | 238 | 0·178593 | 9 947063 | 424 | 0·052937 | 0·125656 | 186 | 9·874344 | 56 | 29 |
| 32 | 8 | 9·821550 | 238 | 0·178450 | 9 947318 | 424 | 0·052682 | 0·125768 | 187 | 9 874232 | 52 | 28 |
| 33 | 12 | 9·821693 | 237 | 0·178307 | 9 947572 | 424 | 0·052428 | 0·125879 | 187 | 9 874121 | 48 | 27 |
| 34 | 16 | 9·821835 | 237 | 0·178165 | 9·947827 | 424 | 0·052173 | 0·125991 | 187 | 9 874009 | 44 | 26 |
| 35 | 20 | 9·821977 | 237 | 0·178023 | 9 948081 | 424 | 0·051919 | 0·126104 | 187 | 9 873896 | 40 | 25 |
| 36 | 24 | 9·822120 | 237 | 0·177880 | 9 948335 | 424 | 0·051665 | 0·126216 | 187 | 9 873784 | 36 | 24 |
| 37 | 28 | 9·822262 | 237 | 0·177738 | 9·948590 | 424 | 0·051410 | 0·126328 | 187 | 9·873672 | 32 | 23 |
| 38 | 32 | 9·822404 | 237 | 0·177596 | 9·948844 | 424 | 0·051156 | 0·126440 | 187 | 9 873560 | 28 | 22 |
| 39 | 36 | 9·822546 | 237 | 0·177454 | 9 949099 | 424 | 0·050901 | 0·126552 | 187 | 9 873448 | 24 | 21 |
| 40 | 40 | 9·822688 | 236 | 0·177312 | 9 949353 | 424 | 0·050647 | 0·126665 | 187 | 9 873335 | 20 | 20 |
| 41 | 44 | 9·822830 | 236 | 0·177170 | 9·949608 | 424 | 0·050392 | 0·126777 | 187 | 9 873223 | 16 | 19 |
| 42 | 48 | 9·822972 | 236 | 0·177028 | 9 949862 | 424 | 0·050138 | 0·126890 | 188 | 9·873110 | 12 | 18 |
| 43 | 52 | 9·823114 | 236 | 0·176886 | 9 950116 | 424 | 0·049884 | 0·127002 | 188 | 9 872998 | 8 | 17 |
| 44 | 56 | 9·823255 | 236 | 0·176745 | 9 950371 | 424 | 0·049629 | 0·127115 | 188 | 9 872885 | 4 | 16 |
| 45 | **47** | 9·823397 | 236 | 0·176603 | 9·950625 | 424 | 0·049375 | 0·127228 | 188 | 9·872772 | **13** | 15 |
| 46 | 4 | 9·823539 | 236 | 0·176461 | 9·950879 | 424 | 0·049121 | 0·127341 | 188 | 9·872659 | 56 | 14 |
| 47 | 8 | 9·823680 | 235 | 0·176320 | 9 951133 | 424 | 0·048867 | 0·127453 | 188 | 9·872547 | 52 | 13 |
| 48 | 12 | 9·823821 | 235 | 0·176179 | 9 951388 | 424 | 0·048612 | 0·127566 | 188 | 9·872434 | 48 | 12 |
| 49 | 16 | 9·823963 | 235 | 0·176037 | 9·951642 | 424 | 0·048358 | 0·127679 | 188 | 9·872321 | 44 | 11 |
| 50 | 20 | 9·824104 | 235 | 0·175896 | 9 951896 | 424 | 0·048104 | 0·127792 | 188 | 9·872208 | 40 | 10 |
| 51 | 24 | 9·824245 | 235 | 0·175755 | 9 952150 | 424 | 0·047850 | 0·127905 | 189 | 9·872095 | 36 | 9 |
| 52 | 28 | 9·824386 | 235 | 0·175614 | 9 952405 | 424 | 0·047595 | 0·128019 | 189 | 9·871981 | 32 | 8 |
| 53 | 32 | 9·824527 | 235 | 0·175473 | 9 952659 | 424 | 0·047341 | 0·128132 | 189 | 9·871868 | 28 | 7 |
| 54 | 36 | 9·824668 | 234 | 0·175332 | 9·952913 | 424 | 0·047087 | 0·128245 | 189 | 9·871755 | 24 | 6 |
| 55 | 40 | 9·824808 | 234 | 0·175192 | 9·953167 | 423 | 0·046833 | 0·128359 | 189 | 9·871641 | 20 | 5 |
| 56 | 44 | 9·824949 | 234 | 0·175051 | 9·953421 | 423 | 0·046579 | 0·128472 | 189 | 9·871528 | 16 | 4 |
| 57 | 48 | 9·825090 | 234 | 0·174910 | 9 953675 | 423 | 0·046325 | 0·128586 | 189 | 9·871414 | 12 | 3 |
| 58 | 52 | 9·825230 | 234 | 0·174770 | 9·953929 | 423 | 0·046071 | 0·128699 | 189 | 9·871301 | 8 | 2 |
| 59 | 56 | 9·825371 | 234 | 0·174629 | 9 954183 | 423 | 0·045817 | 0·128813 | 189 | 9·871187 | 4 | 1 |
| 60 | **48** | 9·825511 | | 0·174489 | 9·954437 | | 0·045563 | 0·128927 | | 9·871073 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | M. s. | ′ |

131° 48°=3h 12m 48°

## LOG. SINES, COSINES, &c.

42° = 2h 48m — 137°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·825511 | 234 | 0·174489 | 9·954437 | 423 | 0·045563 | 0·128927 | 190 | 9·871073 | **12** | 60 |
| 1 | 4 | 9·825651 | 233 | 0·174349 | 9·954691 | 423 | 0·045309 | 0·129040 | 190 | 9·870960 | 56 | 59 |
| 2 | 8 | 9·825791 | 233 | 0·174209 | 9·954946 | 423 | 0·045054 | 0·129154 | 190 | 9·870846 | 52 | 58 |
| 3 | 12 | 9·825931 | 233 | 0·174069 | 9·955200 | 423 | 0·044800 | 0·129268 | 190 | 9·870732 | 48 | 57 |
| 4 | 16 | 9·826071 | 233 | 0·173929 | 9·955454 | 423 | 0·044546 | 0·129382 | 190 | 9·870618 | 44 | 56 |
| 5 | 20 | 9·826211 | 233 | 0·173789 | 9·955708 | 423 | 0·044292 | 0·129496 | 190 | 9·870504 | 40 | 55 |
| 6 | 24 | 9·826351 | 233 | 0·173649 | 9·955961 | 423 | 0·044039 | 0·129610 | 190 | 9·870390 | 36 | 54 |
| 7 | 28 | 9·826491 | 233 | 0·173509 | 9·956215 | 423 | 0·043785 | 0·129724 | 190 | 9·870276 | 32 | 53 |
| 8 | 32 | 9·826631 | 233 | 0·173369 | 9·956469 | 423 | 0·043531 | 0·129839 | 190 | 9·870161 | 28 | 52 |
| 9 | 36 | 9·826770 | 232 | 0·173230 | 9·956723 | 423 | 0·043277 | 0·129953 | 191 | 9·870047 | 24 | 51 |
| 10 | 40 | 9·826910 | 232 | 0·173090 | 9·956977 | 423 | 0·043023 | 0·130067 | 191 | 9·869933 | 20 | 50 |
| 11 | 44 | 9·827049 | 232 | 0·172951 | 9·957231 | 423 | 0·042769 | 0·130182 | 191 | 9·869818 | 16 | 49 |
| 12 | 48 | 9·827189 | 232 | 0·172811 | 9·957485 | 423 | 0·042515 | 0·130296 | 191 | 9·869704 | 12 | 48 |
| 13 | 52 | 9·827328 | 232 | 0·172672 | 9·957739 | 423 | 0·042261 | 0·130411 | 191 | 9·869589 | 8 | 47 |
| 14 | 56 | 9·827467 | 232 | 0·172533 | 9·957993 | 423 | 0·042007 | 0·130526 | 191 | 9·869474 | 4 | 46 |
| 15 | **49** | 9·827606 | 232 | 0·172394 | 9·958247 | 423 | 0·041753 | 0·130640 | 191 | 9·869360 | **11** | 45 |
| 16 | 4 | 9·827745 | 232 | 0·172255 | 9·958500 | 423 | 0·041500 | 0·130755 | 191 | 9·869245 | 56 | 44 |
| 17 | 8 | 9·827884 | 232 | 0·172116 | 9·958754 | 423 | 0·041246 | 0·130870 | 191 | 9·869130 | 52 | 43 |
| 18 | 12 | 9·828023 | 231 | 0·171977 | 9·959008 | 423 | 0·040992 | 0·130985 | 191 | 9·869015 | 48 | 42 |
| 19 | 16 | 9·828162 | 231 | 0·171838 | 9·959262 | 423 | 0·040738 | 0·131100 | 192 | 9·868900 | 44 | 41 |
| 20 | 20 | 9·828301 | 231 | 0·171699 | 9·959516 | 423 | 0·040484 | 0·131215 | 192 | 9·868785 | 40 | 40 |
| 21 | 24 | 9·828439 | 231 | 0·171561 | 9·959769 | 423 | 0·040231 | 0·131330 | 192 | 9·868670 | 36 | 39 |
| 22 | 28 | 9·828578 | 231 | 0·171422 | 9·960023 | 423 | 0·039977 | 0·131445 | 192 | 9·868555 | 32 | 38 |
| 23 | 32 | 9·828716 | 231 | 0·171284 | 9·960277 | 423 | 0·039723 | 0·131560 | 192 | 9·868440 | 28 | 37 |
| 24 | 36 | 9·828855 | 230 | 0·171145 | 9·960530 | 423 | 0·039470 | 0·131676 | 192 | 9·868324 | 24 | 36 |
| 25 | 40 | 9·828993 | 230 | 0·171007 | 9·960784 | 423 | 0·039216 | 0·131791 | 192 | 9·868209 | 20 | 35 |
| 26 | 44 | 9·829131 | 230 | 0·170869 | 9·961038 | 423 | 0·038962 | 0·131907 | 192 | 9·868093 | 16 | 34 |
| 27 | 48 | 9·829269 | 230 | 0·170731 | 9·961292 | 423 | 0·038708 | 0·132022 | 192 | 9·867978 | 12 | 33 |
| 28 | 52 | 9·829407 | 230 | 0·170593 | 9·961545 | 423 | 0·038455 | 0·132138 | 193 | 9·867862 | 8 | 32 |
| 29 | 56 | 9·829545 | 230 | 0·170455 | 9·961799 | 423 | 0·038201 | 0·132253 | 193 | 9·867747 | 4 | 31 |
| 30 | **50** | 9·829683 | 230 | 0·170317 | 9·962052 | 423 | 0·037948 | 0·132369 | 193 | 9·867631 | **10** | 30 |
| 31 | 4 | 9·829821 | 229 | 0·170179 | 9·962306 | 423 | 0·037694 | 0·132485 | 193 | 9·867515 | 56 | 29 |
| 32 | 8 | 9·829959 | 229 | 0·170041 | 9·962560 | 423 | 0·037440 | 0·132601 | 193 | 9·867399 | 52 | 28 |
| 33 | 12 | 9·830097 | 229 | 0·169903 | 9·962813 | 423 | 0·037187 | 0·132717 | 193 | 9·867283 | 48 | 27 |
| 34 | 16 | 9·830234 | 229 | 0·169766 | 9·963067 | 423 | 0·036933 | 0·132833 | 193 | 9·867167 | 44 | 26 |
| 35 | 20 | 9·830372 | 229 | 0·169628 | 9·963320 | 423 | 0·036680 | 0·132949 | 193 | 9·867051 | 40 | 25 |
| 36 | 24 | 9·830509 | 229 | 0·169491 | 9·963574 | 423 | 0·036426 | 0·133065 | 193 | 9·866935 | 36 | 24 |
| 37 | 28 | 9·830646 | 229 | 0·169354 | 9·963828 | 423 | 0·036172 | 0·133181 | 194 | 9·866819 | 32 | 23 |
| 38 | 32 | 9·830784 | 229 | 0·169216 | 9·964081 | 423 | 0·035919 | 0·133297 | 194 | 9·866703 | 28 | 22 |
| 39 | 36 | 9·830921 | 228 | 0·169079 | 9·964335 | 423 | 0·035665 | 0·133414 | 194 | 9·866585 | 24 | 21 |
| 40 | 40 | 9·831058 | 228 | 0·168942 | 9·964588 | 422 | 0·035412 | 0·133530 | 194 | 9·866470 | 20 | 20 |
| 41 | 44 | 9·831195 | 228 | 0·168805 | 9·964842 | 422 | 0·035158 | 0·133647 | 194 | 9·866353 | 16 | 19 |
| 42 | 48 | 9·831332 | 228 | 0·168668 | 9·965095 | 422 | 0·034905 | 0·133763 | 194 | 9·866237 | 12 | 18 |
| 43 | 52 | 9·831469 | 228 | 0·168531 | 9·965349 | 422 | 0·034651 | 0·133880 | 194 | 9·866120 | 8 | 17 |
| 44 | 56 | 9·831606 | 228 | 0·168394 | 9·965602 | 422 | 0·034398 | 0·133996 | 194 | 9·866004 | 4 | 16 |
| 45 | **51** | 9·831742 | 228 | 0·168258 | 9·965855 | 422 | 0·034145 | 0·134113 | 195 | 9·865887 | **9** | 15 |
| 46 | 4 | 9·831879 | 228 | 0·168121 | 9·966109 | 422 | 0·033891 | 0·134230 | 195 | 9·865770 | 56 | 14 |
| 47 | 8 | 9·832015 | 227 | 0·167985 | 9·966362 | 422 | 0·033638 | 0·134347 | 195 | 9·865653 | 52 | 13 |
| 48 | 12 | 9·832152 | 227 | 0·167848 | 9·966616 | 422 | 0·033384 | 0·134464 | 195 | 9·865536 | 48 | 12 |
| 49 | 16 | 9·832288 | 227 | 0·167712 | 9·966869 | 422 | 0·033131 | 0·134581 | 195 | 9·865419 | 44 | 11 |
| 50 | 20 | 9·832425 | 227 | 0·167575 | 9·967123 | 422 | 0·032877 | 0·134698 | 195 | 9·865302 | 40 | 10 |
| 51 | 24 | 9·832561 | 227 | 0·167439 | 9·967376 | 422 | 0·032624 | 0·134815 | 195 | 9·865185 | 36 | 9 |
| 52 | 28 | 9·832697 | 227 | 0·167303 | 9·967629 | 422 | 0·032371 | 0·134932 | 195 | 9·865068 | 32 | 8 |
| 53 | 32 | 9·832833 | 227 | 0·167167 | 9·967883 | 422 | 0·032117 | 0·135050 | 195 | 9·864950 | 28 | 7 |
| 54 | 36 | 9·832969 | 226 | 0·167031 | 9·968136 | 422 | 0·031864 | 0·135167 | 196 | 9·864833 | 24 | 6 |
| 55 | 40 | 9·833105 | 226 | 0·166895 | 9·968389 | 422 | 0·031611 | 0·135284 | 196 | 9·864716 | 20 | 5 |
| 56 | 44 | 9·833241 | 226 | 0·166759 | 9·968643 | 422 | 0·031357 | 0·135402 | 196 | 9·864598 | 16 | 4 |
| 57 | 48 | 9·833377 | 226 | 0·166623 | 9·968896 | 422 | 0·031104 | 0·135519 | 196 | 9·864481 | 12 | 3 |
| 58 | 52 | 9·833512 | 226 | 0·166488 | 9·969149 | 422 | 0·030851 | 0·135637 | 196 | 9·864363 | 8 | 2 |
| 59 | 56 | 9·833648 | 226 | 0·166352 | 9·969403 | 422 | 0·030597 | 0·135755 | 196 | 9·864245 | 4 | 1 |
| 60 | **52** | 9·833783 | 226 | 0·166217 | 9·969656 | 422 | 0·030344 | 0·135873 | 196 | 9·864127 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

132° — 47° = 3h 8m — 47°

## LOG. SINES, COSINES, &c.

43° 43°=2h 52m 136°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·833783 | 226 | 0·166217 | 9·969656 | 422 | 0·030344 | 0·135873 | 196 | 9·864127 | 8 | 60 |
| 1 | 4 | 9·833919 | 225 | 0·166081 | 9·969909 | 422 | 0·030091 | 0·135990 | 196 | 9·864010 | 56 | 59 |
| 2 | 8 | 9·834054 | 225 | 0·165946 | 9·970162 | 422 | 0·029838 | 0·136108 | 197 | 9·863892 | 52 | 58 |
| 3 | 12 | 9·834189 | 225 | 0·165811 | 9·970416 | 422 | 0·029584 | 0·136226 | 197 | 9·863774 | 48 | 57 |
| 4 | 16 | 9·834325 | 225 | 0·165675 | 9·970669 | 422 | 0·029331 | 0·136344 | 197 | 9·863656 | 44 | 56 |
| 5 | 20 | 9·834460 | 225 | 0·165540 | 9·970922 | 422 | 0·029078 | 0·136462 | 197 | 9·863538 | 40 | 55 |
| 6 | 24 | 9·834595 | 225 | 0·165405 | 9·971175 | 422 | 0·028825 | 0·136581 | 197 | 9·863419 | 36 | 54 |
| 7 | 28 | 9·834730 | 225 | 0·165270 | 9·971429 | 422 | 0·028571 | 0·136699 | 197 | 9·863301 | 32 | 53 |
| 8 | 32 | 9·834865 | 225 | 0·165135 | 9·971682 | 422 | 0·028318 | 0·136817 | 197 | 9·863183 | 28 | 52 |
| 9 | 36 | 9·834999 | 224 | 0·165001 | 9·971935 | 422 | 0·028065 | 0·136936 | 197 | 9·863064 | 24 | 51 |
| 10 | 40 | 9·835134 | 224 | 0·164866 | 9·972188 | 422 | 0·027812 | 0·137054 | 198 | 9 862946 | 20 | 50 |
| 11 | 44 | 9·835269 | 224 | 0·164731 | 9·972441 | 422 | 0·027559 | 0·137173 | 198 | 9·862827 | 16 | 49 |
| 12 | 48 | 9·835403 | 224 | 0·164597 | 9·972695 | 422 | 0·027305 | 0·137291 | 198 | 9·862709 | 12 | 48 |
| 13 | 52 | 9·835538 | 224 | 0·164462 | 9·972948 | 422 | 0·027052 | 0·137410 | 198 | 9 862590 | 8 | 47 |
| 14 | 56 | 9·835672 | 224 | 0·164328 | 9·973201 | 422 | 0·026799 | 0·137529 | 198 | 9·862471 | 4 | 46 |
| 15 | **53** | 9·835807 | 224 | 0·164193 | 9 973454 | 422 | 0·026546 | 0·137647 | 198 | 9·862353 | **7** | 45 |
| 16 | 4 | 9·835941 | 224 | 0·164059 | 9·973707 | 422 | 0·026293 | 0·137766 | 198 | 9·862234 | 56 | 44 |
| 17 | 8 | 9·836075 | 224 | 0·163925 | 9·973960 | 422 | 0·026040 | 0·137885 | 198 | 9·862115 | 52 | 43 |
| 18 | 12 | 9·836209 | 223 | 0·163791 | 9·974213 | 422 | 0·025787 | 0·138004 | 198 | 9 861996 | 48 | 42 |
| 19 | 16 | 9·836343 | 223 | 0·163657 | 9·974466 | 422 | 0·025534 | 0·138123 | 198 | 9 861877 | 44 | 41 |
| 20 | 20 | 9·836477 | 223 | 0·163523 | 9·974720 | 422 | 0·025280 | 0·138242 | 198 | 9·861758 | 40 | 40 |
| 21 | 24 | 9·836611 | 223 | 0·163389 | 9·974973 | 422 | 0·025027 | 0·138362 | 199 | 9·861638 | 36 | 39 |
| 22 | 28 | 9·836745 | 223 | 0·163255 | 9·975226 | 422 | 0·024774 | 0·138481 | 199 | 9·861519 | 32 | 38 |
| 23 | 32 | 9·836878 | 223 | 0·163122 | 9·975479 | 422 | 0·024521 | 0·138600 | 199 | 9 861400 | 28 | 37 |
| 24 | 36 | 9·837012 | 222 | 0·162988 | 9·975732 | 422 | 0·024268 | 0·138720 | 199 | 9 861280 | 24 | 36 |
| 25 | 40 | 9·837146 | 222 | 0·162854 | 9·975985 | 422 | 0·024015 | 0·138839 | 199 | 9·861161 | 20 | 35 |
| 26 | 44 | 9·837279 | 222 | 0·162721 | 9·976238 | 422 | 0·023762 | 0·138959 | 199 | 9·861041 | 16 | 34 |
| 27 | 48 | 9·837412 | 222 | 0·162588 | 9 976491 | 422 | 0·023509 | 0·139078 | 199 | 9·860922 | 12 | 33 |
| 28 | 52 | 9·837546 | 222 | 0·162454 | 9·976744 | 422 | 0·023256 | 0·139198 | 199 | 9·860802 | 8 | 32 |
| 29 | 56 | 9·837679 | 222 | 0·162321 | 9·976997 | 422 | 0·023003 | 0·139318 | 199 | 9·860682 | 4 | 31 |
| 30 | **54** | 9·837812 | 222 | 0·162188 | 9·977250 | 422 | 0·022750 | 0·139438 | 200 | 9 860562 | **6** | 30 |
| 31 | 4 | 9·837945 | 222 | 0·162055 | 9·977503 | 422 | 0·022497 | 0·139558 | 200 | 9·860442 | 56 | 29 |
| 32 | 8 | 9·838078 | 221 | 0·161922 | 9·977756 | 422 | 0·022244 | 0·139678 | 200 | 9·860322 | 52 | 28 |
| 33 | 12 | 9·838211 | 221 | 0·161789 | 9·978009 | 422 | 0·021991 | 0·139798 | 200 | 9·860202 | 48 | 27 |
| 34 | 16 | 9·838344 | 221 | 0·161656 | 9·978262 | 422 | 0·021738 | 0·139918 | 200 | 9·860082 | 44 | 26 |
| 35 | 20 | 9·838477 | 221 | 0·161523 | 9·978515 | 422 | 0·021485 | 0·140038 | 200 | 9·859962 | 40 | 25 |
| 36 | 24 | 9·838610 | 221 | 0·161390 | 9·978768 | 422 | 0·021232 | 0·140158 | 200 | 9·859842 | 36 | 24 |
| 37 | 28 | 9·838742 | 221 | 0·161258 | 9·979021 | 422 | 0·020979 | 0·140279 | 200 | 9·859721 | 32 | 23 |
| 38 | 32 | 9·838875 | 221 | 0·161125 | 9·979274 | 422 | 0·020726 | 0·140399 | 201 | 9·859601 | 28 | 22 |
| 39 | 36 | 9·839007 | 221 | 0·160993 | 9·979527 | 422 | 0·020473 | 0·140520 | 201 | 9·859480 | 24 | 21 |
| 40 | 40 | 9·839140 | 220 | 0·160860 | 9·979780 | 422 | 0·020220 | 0·140640 | 201 | 9·859360 | 20 | 20 |
| 41 | 44 | 9·839272 | 220 | 0·160728 | 9·980033 | 422 | 0·019967 | 0·140761 | 201 | 9·859239 | 16 | 19 |
| 42 | 48 | 9·839404 | 220 | 0·160596 | 9·980286 | 422 | 0·019714 | 0·140881 | 201 | 9·859119 | 12 | 18 |
| 43 | 52 | 9·839536 | 220 | 0·160464 | 9·980538 | 422 | 0·019462 | 0·141002 | 201 | 9·858998 | 8 | 17 |
| 44 | 56 | 9·839668 | 220 | 0·160332 | 9·980791 | 421 | 0·019209 | 0·141123 | 201 | 9·858877 | 4 | 16 |
| 45 | **55** | 9·839800 | 220 | 0·160200 | 9·981044 | 421 | 0·018956 | 0·141244 | 202 | 9·858756 | **5** | 15 |
| 46 | 4 | 9·839932 | 220 | 0·160068 | 9·981297 | 421 | 0·018703 | 0·141365 | 202 | 9·858635 | 56 | 14 |
| 47 | 8 | 9·840064 | 219 | 0·159936 | 9·981550 | 421 | 0·018450 | 0·141486 | 202 | 9·858514 | 52 | 13 |
| 48 | 12 | 9·840196 | 219 | 0·159804 | 9·981803 | 421 | 0·018197 | 0·141607 | 202 | 9·858393 | 48 | 12 |
| 49 | 16 | 9·840328 | 219 | 0·159672 | 9·982056 | 421 | 0·017944 | 0·141728 | 202 | 9·858272 | 44 | 11 |
| 50 | 20 | 9·840459 | 219 | 0·159541 | 9·982309 | 421 | 0·017691 | 0·141849 | 202 | 9·858151 | 40 | 10 |
| 51 | 24 | 9·840591 | 219 | 0·159409 | 9·982562 | 421 | 0·017438 | 0·141971 | 202 | 9·858029 | 36 | 9 |
| 52 | 28 | 9·840722 | 219 | 0·159278 | 9·982814 | 421 | 0·017186 | 0·142092 | 202 | 9·857908 | 32 | 8 |
| 53 | 32 | 9·840854 | 219 | 0·159146 | 9·983067 | 421 | 0·016933 | 0·142214 | 202 | 9·857786 | 28 | 7 |
| 54 | 36 | 9·840985 | 219 | 0·159015 | 9·983320 | 421 | 0·016680 | 0·142335 | 203 | 9·857665 | 24 | 6 |
| 55 | 40 | 9·841116 | 218 | 0·158884 | 9·983573 | 421 | 0·016427 | 0·142457 | 203 | 9·857543 | 20 | 5 |
| 56 | 44 | 9·841247 | 218 | 0·158753 | 9·983826 | 421 | 0·016174 | 0·142578 | 203 | 9·857422 | 16 | 4 |
| 57 | 48 | 9·841378 | 218 | 0·158622 | 9·984079 | 421 | 0·015921 | 0·142700 | 203 | 9·857300 | 12 | 3 |
| 58 | 52 | 9·841509 | 218 | 0·158491 | 9·984332 | 421 | 0·015668 | 0·142822 | 203 | 9·857178 | 8 | 2 |
| 59 | 56 | 9·841640 | 218 | 0·158360 | 9·984584 | 421 | 0·015416 | 0·142944 | 203 | 9·857056 | 4 | 1 |
| 60 | **56** | 9·841771 | 218 | 0·158229 | 9·984837 | 421 | 0·015163 | 0·143066 | 203 | 9·856934 | 0 | 0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

133° 46°=3h 4m 46°

## LOG. SINES, COSINES, &c.

44° 44°=2h 56m 135°

| ′ | M. s. | Sine. | D. | Cosec. | Tangent. | D. | Cotang. | Secant. | D. | Cosine. | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 9·841771 | 218 | 0·158229 | 9 984837 | 421 | 0·015163 | 0·143066 | 203 | 9 856934 | 4 | 60 |
| 1 | 4 | 9·841902 | 218 | 0·158098 | 9 985090 | 421 | 0·014910 | 0·143188 | 203 | 9 856812 | 56 | 59 |
| 2 | 8 | 9·842033 | 218 | 0·157967 | 9 985343 | 421 | 0·014657 | 0·143310 | 204 | 9 856690 | 52 | 58 |
| 3 | 12 | 9·842163 | 217 | 0·157837 | 9 985596 | 421 | 0·014404 | 0·143432 | 204 | 9 856568 | 48 | 57 |
| 4 | 16 | 9·842294 | 217 | 0·157706 | 9 985848 | 421 | 0·014152 | 0·143554 | 204 | 9 856446 | 44 | 56 |
| 5 | 20 | 9·842424 | 217 | 0·157576 | 9 986101 | 421 | 0·013899 | 0·143677 | 204 | 9 856323 | 40 | 55 |
| 6 | 24 | 9·842555 | 217 | 0·157445 | 9 986354 | 421 | 0·013646 | 0·143799 | 204 | 9 856201 | 36 | 54 |
| 7 | 28 | 9·842685 | 217 | 0·157315 | 9 986607 | 421 | 0·013393 | 0·143922 | 204 | 9 856078 | 32 | 53 |
| 8 | 32 | 9·842815 | 217 | 0·157185 | 9 986860 | 421 | 0·013140 | 0·144044 | 204 | 9 855956 | 28 | 52 |
| 9 | 36 | 9·842946 | 217 | 0·157054 | 9 987112 | 421 | 0·012888 | 0·144167 | 204 | 9 855833 | 24 | 51 |
| 10 | 40 | 9·843076 | 217 | 0·156924 | 9 987365 | 421 | 0·012635 | 0·144289 | 205 | 9 855711 | 20 | 50 |
| 11 | 44 | 9·843206 | 216 | 0·156794 | 9 987618 | 421 | 0·012382 | 0·144412 | 205 | 9 855588 | 16 | 49 |
| 12 | 48 | 9·843336 | 216 | 0·156664 | 9 987871 | 421 | 0·012129 | 0·144535 | 205 | 9 855465 | 12 | 48 |
| 13 | 52 | 9·843466 | 216 | 0·156534 | 9 988123 | 421 | 0·011877 | 0·144658 | 205 | 9 855342 | 8 | 47 |
| 14 | 56 | 9·843595 | 216 | 0·156405 | 9 988376 | 421 | 0·011624 | 0·144781 | 205 | 9 855219 | 4 | 46 |
| 15 | 57 | 9·843725 | 216 | 0·156275 | 9 988629 | 421 | 0·011371 | 0·144904 | 205 | 9 855096 | 3 | 45 |
| 16 | 4 | 9·843855 | 216 | 0·156145 | 9 988882 | 421 | 0·011118 | 0·145027 | 205 | 9 854973 | 56 | 44 |
| 17 | 8 | 9·843984 | 216 | 0·156016 | 9 989134 | 421 | 0·010866 | 0·145150 | 205 | 9 854850 | 52 | 43 |
| 18 | 12 | 9·844114 | 215 | 0·155886 | 9 989387 | 421 | 0·010613 | 0·145273 | 206 | 9 854727 | 48 | 42 |
| 19 | 16 | 9·844243 | 215 | 0·155757 | 9 989640 | 421 | 0·010360 | 0·145397 | 206 | 9 854603 | 44 | 41 |
| 20 | 20 | 9·844372 | 215 | 0·155628 | 9 989893 | 421 | 0·010107 | 0·145520 | 206 | 9 854480 | 40 | 40 |
| 21 | 24 | 9·844502 | 215 | 0·155498 | 9 990145 | 421 | 0·009855 | 0·145644 | 206 | 9 854356 | 36 | 39 |
| 22 | 28 | 9·844631 | 215 | 0·155369 | 9 990398 | 421 | 0·009602 | 0·145767 | 206 | 9 854233 | 32 | 38 |
| 23 | 32 | 9·844760 | 215 | 0·155240 | 9 990651 | 421 | 0·009349 | 0·145891 | 206 | 9 854109 | 28 | 37 |
| 24 | 36 | 9·844889 | 215 | 0·155111 | 9 990903 | 421 | 0·009097 | 0·146014 | 206 | 9 853986 | 24 | 36 |
| 25 | 40 | 9·845018 | 215 | 0·154982 | 9 991156 | 421 | 0·008844 | 0·146138 | 206 | 9 853862 | 20 | 35 |
| 26 | 44 | 9·845147 | 215 | 0·154853 | 9 991409 | 421 | 0·008591 | 0·146262 | 206 | 9 853738 | 16 | 34 |
| 27 | 48 | 9·845276 | 214 | 0·154724 | 9 991662 | 421 | 0·008338 | 0·146386 | 206 | 9·853614 | 12 | 33 |
| 28 | 52 | 9·845405 | 214 | 0·154595 | 9·991914 | 421 | 0·008086 | 0·146510 | 207 | 9 853490 | 8 | 32 |
| 29 | 56 | 9·845533 | 214 | 0·154467 | 9·992167 | 421 | 0·007833 | 0·146634 | 207 | 9·853366 | 4 | 31 |
| 30 | 58 | 9·845662 | 214 | 0·154338 | 9·992420 | 421 | 0·007580 | 0·146758 | 207 | 9 853242 | 2 | 30 |
| 31 | 4 | 9·845790 | 214 | 0·154210 | 9·992672 | 421 | 0·007328 | 0·146882 | 207 | 9·853118 | 56 | 29 |
| 32 | 8 | 9·845919 | 214 | 0·154081 | 9·992925 | 421 | 0·007075 | 0·147006 | 207 | 9·852994 | 52 | 28 |
| 33 | 12 | 9·846047 | 214 | 0·153953 | 9·993178 | 421 | 0·006822 | 0·147131 | 207 | 9·852869 | 48 | 27 |
| 34 | 16 | 9·846175 | 214 | 0·153825 | 9·993431 | 421 | 0·006569 | 0·147255 | 207 | 9·852745 | 44 | 26 |
| 35 | 20 | 9·846304 | 214 | 0·153696 | 9·993683 | 421 | 0·006317 | 0·147380 | 207 | 9 852620 | 40 | 25 |
| 36 | 24 | 9·846432 | 214 | 0·153568 | 9·993936 | 421 | 0·006064 | 0·147504 | 208 | 9·852496 | 36 | 24 |
| 37 | 28 | 9·846560 | 213 | 0·153440 | 9·994189 | 421 | 0·005811 | 0·147629 | 208 | 9·852371 | 32 | 23 |
| 38 | 32 | 9·846688 | 213 | 0·153312 | 9·994441 | 421 | 0·005559 | 0·147753 | 208 | 9 852247 | 28 | 22 |
| 39 | 36 | 9·846816 | 213 | 0·153184 | 9·994694 | 421 | 0·005306 | 0·147878 | 208 | 9·852122 | 24 | 21 |
| 40 | 40 | 9·846944 | 213 | 0·153056 | 9·994947 | 421 | 0·005053 | 0·148003 | 208 | 9·851997 | 20 | 20 |
| 41 | 44 | 9·847071 | 213 | 0·152929 | 9·995199 | 421 | 0·004801 | 0·148128 | 208 | 9·851872 | 16 | 19 |
| 42 | 48 | 9·847199 | 213 | 0·152801 | 9·995452 | 421 | 0·004548 | 0·148253 | 208 | 9·851747 | 12 | 18 |
| 43 | 52 | 9·847327 | 213 | 0·152673 | 9·995705 | 421 | 0·004295 | 0·148378 | 208 | 9·851622 | 8 | 17 |
| 44 | 56 | 9·847454 | 212 | 0·152546 | 9·995957 | 421 | 0·004043 | 0·148503 | 209 | 9·851497 | 4 | 16 |
| 45 | 59 | 9·847582 | 212 | 0·152418 | 9·996210 | 421 | 0·003790 | 0·148628 | 209 | 9·851372 | 1 | 15 |
| 46 | 4 | 9·847709 | 212 | 0·152291 | 9·996463 | 421 | 0·003537 | 0·148754 | 209 | 9·851246 | 56 | 14 |
| 47 | 8 | 9·847836 | 212 | 0·152164 | 9·996715 | 421 | 0·003285 | 0·148879 | 209 | 9·851121 | 52 | 13 |
| 48 | 12 | 9·847964 | 212 | 0·152036 | 9·996968 | 421 | 0·003032 | 0·149004 | 209 | 9·850996 | 48 | 12 |
| 49 | 16 | 9·848091 | 212 | 0·151909 | 9·997221 | 421 | 0·002779 | 0·149130 | 209 | 9·850870 | 44 | 11 |
| 50 | 20 | 9·848218 | 212 | 0·151782 | 9·997473 | 421 | 0·002527 | 0·149255 | 209 | 9·850745 | 40 | 10 |
| 51 | 24 | 9·848345 | 212 | 0·151655 | 9·997726 | 421 | 0·002274 | 0·149381 | 209 | 9·850619 | 36 | 9 |
| 52 | 28 | 9·848472 | 211 | 0·151528 | 9 997979 | 421 | 0·002021 | 0·149507 | 210 | 9·850493 | 32 | 8 |
| 53 | 32 | 9·848599 | 211 | 0·151401 | 9 998231 | 421 | 0·001769 | 0·149632 | 210 | 9·850368 | 28 | 7 |
| 54 | 36 | 9·848726 | 211 | 0·151274 | 9·998484 | 421 | 0·001516 | 0·149758 | 210 | 9·850242 | 24 | 6 |
| 55 | 40 | 9·848852 | 211 | 0·151148 | 9·998737 | 421 | 0·001263 | 0·149884 | 210 | 9·850116 | 20 | 5 |
| 56 | 44 | 9·848979 | 211 | 0·151021 | 9·998989 | 421 | 0·001011 | 0·150010 | 210 | 9·849990 | 16 | 4 |
| 57 | 48 | 9·849106 | 211 | 0·150894 | 9·999242 | 421 | 0·000758 | 0·150136 | 210 | 9·849864 | 12 | 3 |
| 58 | 52 | 9·849232 | 211 | 0·150768 | 9·999495 | 421 | 0·000505 | 0·150262 | 210 | 9·849738 | 8 | 2 |
| 59 | 56 | 9·849359 | 211 | 0·150641 | 9 999747 | 421 | 0·000253 | 0·150389 | 210 | 9·849611 | 4 | 1 |
| 60 | 60 | 9·849485 | 211 | 0·150515 | 0·000000 | 421 | 0·000000 | 0·150515 | 210 | 9·849485 | 0 | ·0 |
| ′ | | Cosine. | D. | Secant. | Cotang. | D. | Tangent. | Cosec. | D. | Sine. | s. M. | ′ |

134° 45°=3h 0m 45°

## FOR INTERPOLATION.

| Unit or ″ | Difference for 100. | | | | | | | | | | | | | | | | | | | | Unit or ″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 30 | 40 | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·2 | 0·3 | 0·4 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·4 | 0·6 | 0·8 | 2 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0·6 | 0·9 | 1·2 | 3 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0·8 | 1·2 | 1·6 | 4 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0·5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1·0 | 1·5 | 2·0 | 5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0·6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1·2 | 1·8 | 2·4 | 6 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0·7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1·4 | 2·1 | 2·8 | 7 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0·8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1·6 | 2·4 | 3·2 | 8 |
| 9 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0·9 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1·8 | 2·7 | 3·6 | 9 |
| 10 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1·0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2·0 | 3·0 | 4·0 | 10 |
| 11 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1·1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2·2 | 3·3 | 4·4 | 11 |
| 12 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1·2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2·4 | 3·6 | 4·8 | 12 |
| 13 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1·3 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2·6 | 3·9 | 5·2 | 13 |
| 14 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1·4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 2·8 | 4·2 | 5·6 | 14 |
| 15 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1·5 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3·0 | 4·5 | 6·0 | 15 |
| 16 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1·6 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3·2 | 4·8 | 6·4 | 16 |
| 17 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1·7 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3·4 | 5·1 | 6·8 | 17 |
| 18 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1·8 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3·6 | 5·4 | 7·2 | 18 |
| 19 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1·9 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 3·8 | 5·7 | 7·6 | 19 |
| 20 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2·0 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4·0 | 6·0 | 8·0 | 20 |
| 21 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2·1 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4·2 | 6·3 | 8·4 | 21 |
| 22 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2·2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4·4 | 6·6 | 8·8 | 22 |
| 23 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2·3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4·6 | 6·9 | 9·2 | 23 |
| 24 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2·4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 4·8 | 7·2 | 9·6 | 24 |
| 25 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2·5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5·0 | 7·5 | 10·0 | 25 |
| 26 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2·6 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5·2 | 7·8 | 10·4 | 26 |
| 27 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2·7 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5·4 | 8·1 | 10·8 | 27 |
| 28 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 2·8 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5·6 | 8·4 | 11·2 | 28 |
| 29 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 2·9 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 5·8 | 8·7 | 11·6 | 29 |
| 30 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3·0 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6·0 | 9·0 | 12·0 | 30 |
| 31 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3·1 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6·2 | 9·3 | 12·4 | 31 |
| 32 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3·2 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6·4 | 9·6 | 12·8 | 32 |
| 33 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3·3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6·6 | 9·9 | 13·2 | 33 |
| 34 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3·4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6·8 | 10·2 | 13·6 | 34 |
| 35 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3·5 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 7·0 | 10·5 | 14·0 | 35 |
| 36 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3·6 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 7·2 | 10·8 | 14·4 | 36 |
| 37 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3·7 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7·4 | 11·1 | 14·8 | 37 |
| 38 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3·8 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7·6 | 11·4 | 15·2 | 38 |
| 39 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 3·9 | 4 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 7·8 | 11·7 | 15·6 | 39 |
| 40 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4·0 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 8 | 8·0 | 12·0 | 16·0 | 40 |
| 41 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4·1 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 8 | 8·2 | 12·3 | 16·4 | 41 |
| 42 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 4·2 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 8·4 | 12·6 | 16·8 | 42 |
| 43 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 4·3 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 8 | 8 | 8·6 | 12·9 | 17·2 | 43 |
| 44 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 8 | 8 | 8·8 | 13·2 | 17·6 | 44 |
| 45 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·5 | 5 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9·0 | 13·5 | 18·0 | 45 |
| 46 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·6 | 5 | 6 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9·2 | 13·8 | 18·4 | 46 |
| 47 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·7 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 9·4 | 14·1 | 18·8 | 47 |
| 48 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·8 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 9·6 | 14·4 | 19·2 | 48 |
| 49 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4·9 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 9·8 | 14·7 | 19·6 | 49 |
| 50 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5·0 | 5 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10·0 | 15·0 | 20·0 | 50 |
| 51 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·1 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10 | 10·2 | 15·3 | 20·4 | 51 |
| 52 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·2 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10 | 10·4 | 15·6 | 20·8 | 52 |
| 53 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·3 | 6 | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 10 | 10·6 | 15·9 | 21·2 | 53 |
| 54 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·4 | 6 | 6 | 7 | 8 | 8 | 8 | 9 | 10 | 10 | 10·8 | 16·2 | 21·6 | 54 |
| 55 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·5 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 11·0 | 16·5 | 22·0 | 55 |
| 56 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5·6 | 6 | 7 | 7 | 8 | 8 | 9 | 9 | 10 | 11 | 11·2 | 16·8 | 22·4 | 56 |
| 57 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 5·7 | 6 | 7 | 7 | 8 | 9 | 9 | 10 | 10 | 11 | 11·4 | 17·1 | 22·8 | 57 |
| 58 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 5·8 | 6 | 7 | 7 | 8 | 9 | 9 | 10 | 10 | 11 | 11·6 | 17·4 | 23·2 | 58 |
| 59 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 5·9 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 11 | 11 | 11·8 | 17·7 | 23·6 | 59 |
| 60 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6·0 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 11 | 11 | 12·0 | 18·0 | 24·0 | 60 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 30 | 40 | |

## FOR INTERPOLATION.

| Unit or ″ | Difference for 100. | | | | | | | | | | | | | | | | | Unit or ″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 60 | 70 | 80 | 90 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | |
| 1 | 0·5 | 0·6 | 0·7 | 0·8 | 0·9 | 1·0 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 1 |
| 2 | 1·0 | 1·2 | 1·4 | 1·6 | 1·8 | 2·0 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 2 |
| 3 | 1·5 | 1·8 | 2·1 | 2·4 | 2·7 | 3·0 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 3 |
| 4 | 2·0 | 2·4 | 2·8 | 3·2 | 3·6 | 4·0 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 10 | 11 | 12 | 13 | 4 |
| 5 | 2·5 | 3·0 | 3·5 | 4·0 | 4·5 | 5·0 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 13 | 15 | 16 | 5 |
| 6 | 3·0 | 3·6 | 4·2 | 4·8 | 5·4 | 6·0 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 16 | 16 | 18 | 19 | 6 |
| 7 | 3·5 | 4·2 | 4·9 | 5·6 | 6·3 | 7·0 | 8 | 10 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 7 |
| 8 | 4·0 | 4·8 | 5·6 | 6·4 | 7·2 | 8·0 | 10 | 11 | 13 | 14 | 16 | 18 | 19 | 21 | 21 | 24 | 26 | 8 |
| 9 | 4·5 | 5·4 | 6·3 | 7·2 | 8·1 | 9·0 | 11 | 13 | 14 | 16 | 18 | 20 | 22 | 23 | 24 | 27 | 29 | 9 |
| 10 | 5·0 | 6·0 | 7·0 | 8·0 | 9·0 | 10·0 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 10 |
| 11 | 5·5 | 6·6 | 7·7 | 8·8 | 9·9 | 11·0 | 13 | 15 | 18 | 20 | 22 | 24 | 26 | 29 | 31 | 33 | 35 | 11 |
| 12 | 6·0 | 7·2 | 8·4 | 9·6 | 10·8 | 12·0 | 14 | 17 | 19 | 22 | 24 | 26 | 29 | 31 | 34 | 36 | 38 | 12 |
| 13 | 6·5 | 7·8 | 9·1 | 10·4 | 11·7 | 13·0 | 16 | 18 | 21 | 23 | 26 | 29 | 31 | 34 | 36 | 39 | 42 | 13 |
| 14 | 7·0 | 8·4 | 9·8 | 11·2 | 12·6 | 14·0 | 17 | 20 | 22 | 25 | 28 | 31 | 34 | 36 | 39 | 42 | 45 | 14 |
| 15 | 7·5 | 9·0 | 10·5 | 12·0 | 13·5 | 15·0 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 15 |
| 16 | 8·0 | 9 6 | 11·2 | 12·8 | 14·4 | 16·0 | 19 | 22 | 26 | 29 | 32 | 35 | 38 | 42 | 45 | 48 | 51 | 16 |
| 17 | 8·5 | 10·2 | 11·9 | 13·6 | 15·3 | 17·0 | 20 | 24 | 27 | 30 | 34 | 37 | 41 | 44 | 48 | 51 | 54 | 17 |
| 18 | 9·0 | 10·8 | 12·6 | 14·4 | 16·2 | 18·0 | 22 | 25 | 29 | 32 | 36 | 40 | 43 | 47 | 50 | 54 | 58 | 18 |
| 19 | 9·5 | 11·4 | 13·3 | 15·2 | 17·1 | 19·0 | 23 | 27 | 30 | 34 | 38 | 42 | 46 | 49 | 53 | 57 | 61 | 19 |
| 20 | 10·0 | 12·0 | 14·0 | 16·0 | 18·0 | 20·0 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 20 |
| 21 | 10·5 | 12·6 | 14·7 | 16·8 | 18·9 | 21·0 | 25 | 29 | 34 | 38 | 42 | 46 | 50 | 55 | 59 | 63 | 67 | 21 |
| 22 | 11·0 | 13·2 | 15·4 | 17·6 | 19·8 | 22·0 | 26 | 31 | 35 | 40 | 44 | 48 | 53 | 57 | 62 | 66 | 70 | 22 |
| 23 | 11·5 | 13·8 | 16·1 | 18·4 | 20·7 | 23·0 | 28 | 32 | 37 | 41 | 46 | 51 | 55 | 60 | 64 | 69 | 74 | 23 |
| 24 | 12·0 | 14·4 | 16·8 | 19·2 | 21·6 | 24·0 | 29 | 34 | 38 | 43 | 48 | 53 | 58 | 62 | 67 | 72 | 77 | 24 |
| 25 | 12·5 | 15·0 | 17·5 | 20·0 | 22·5 | 25·0 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 25 |
| 26 | 13·0 | 15·6 | 18·2 | 20·8 | 23·4 | 26·0 | 31 | 36 | 42 | 47 | 52 | 57 | 62 | 68 | 73 | 78 | 83 | 26 |
| 27 | 13·5 | 16·2 | 18·9 | 21·6 | 24·3 | 27·0 | 32 | 38 | 43 | 49 | 54 | 59 | 65 | 70 | 76 | 81 | 86 | 27 |
| 28 | 14·0 | 16·8 | 19·6 | 22·4 | 25·2 | 28·0 | 34 | 39 | 45 | 50 | 56 | 62 | 67 | 73 | 78 | 84 | 90 | 28 |
| 29 | 14·5 | 17·4 | 20·3 | 23·2 | 26·1 | 29·0 | 35 | 41 | 46 | 52 | 58 | 64 | 70 | 75 | 81 | 87 | 93 | 29 |
| 30 | 15·0 | 18·0 | 21·0 | 24·0 | 27·0 | 30·0 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 30 |
| 31 | 15·5 | 18·6 | 21·7 | 24·8 | 27·9 | 31·0 | 37 | 43 | 50 | 56 | 62 | 68 | 74 | 81 | 87 | 93 | 99 | 31 |
| 32 | 16·0 | 19·2 | 22·4 | 25·6 | 28·8 | 32·0 | 38 | 45 | 51 | 58 | 64 | 70 | 77 | 83 | 90 | 96 | 102 | 32 |
| 33 | 16·5 | 19·8 | 23·1 | 26·4 | 29·7 | 33·0 | 40 | 46 | 53 | 59 | 66 | 73 | 79 | 86 | 92 | 99 | 106 | 33 |
| 34 | 17·0 | 20·4 | 23·8 | 27·2 | 30·6 | 34·0 | 41 | 48 | 54 | 61 | 68 | 75 | 82 | 88 | 95 | 102 | 109 | 34 |
| 35 | 17·5 | 21·0 | 24·5 | 28·0 | 31·5 | 35·0 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 | 35 |
| 36 | 18·0 | 21·6 | 25·2 | 28·8 | 32·4 | 36·0 | 43 | 50 | 58 | 65 | 72 | 79 | 86 | 94 | 101 | 108 | 115 | 36 |
| 37 | 18·5 | 22·2 | 25·9 | 29·6 | 33·3 | 37·0 | 44 | 52 | 59 | 67 | 74 | 81 | 89 | 96 | 104 | 111 | 118 | 37 |
| 38 | 19·0 | 22·8 | 26·6 | 30·4 | 34·2 | 38·0 | 46 | 53 | 61 | 68 | 76 | 84 | 91 | 99 | 106 | 114 | 122 | 38 |
| 39 | 19·5 | 23·4 | 27·3 | 31·2 | 35·1 | 39·0 | 47 | 55 | 62 | 70 | 78 | 86 | 94 | 101 | 109 | 117 | 125 | 39 |
| 40 | 20·0 | 24·0 | 28·0 | 32·0 | 36·0 | 40·0 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 | 128 | 40 |
| 41 | 20·5 | 24·6 | 28·7 | 32·8 | 36 9 | 41·0 | 49 | 57 | 66 | 74 | 82 | 90 | 98 | 107 | 115 | 123 | 131 | 41 |
| 42 | 21·0 | 25·2 | 29·4 | 33·6 | 37·8 | 42·0 | 50 | 59 | 67 | 76 | 84 | 92 | 101 | 109 | 118 | 126 | 134 | 42 |
| 43 | 21·5 | 25·8 | 30·1 | 34·4 | 38·7 | 43·0 | 52 | 60 | 69 | 77 | 86 | 95 | 103 | 112 | 120 | 129 | 138 | 43 |
| 44 | 22·0 | 26·4 | 30·8 | 35·2 | 39·6 | 44·0 | 53 | 62 | 70 | 79 | 88 | 97 | 106 | 114 | 123 | 132 | 141 | 44 |
| 45 | 22·5 | 27·0 | 31·5 | 36·0 | 40·5 | 45·0 | 54 | 64 | 72 | 81 | 90 | 99 | 108 | 117 | 126 | 135 | 144 | 45 |
| 46 | 23·0 | 27·6 | 32·2 | 36·8 | 41·4 | 46·0 | 55 | 65 | 74 | 83 | 92 | 101 | 110 | 120 | 129 | 138 | 147 | 46 |
| 47 | 23·5 | 28·2 | 32·9 | 37·6 | 42·3 | 47·0 | 56 | 66 | 75 | 85 | 94 | 103 | 113 | 122 | 132 | 141 | 150 | 47 |
| 48 | 24·0 | 28·8 | 33·6 | 38·4 | 43·2 | 48·0 | 58 | 67 | 77 | 86 | 96 | 106 | 115 | 125 | 134 | 144 | 154 | 48 |
| 49 | 24·5 | 29·4 | 34·3 | 39·2 | 44·1 | 49·0 | 59 | 69 | 78 | 88 | 98 | 108 | 118 | 127 | 137 | 147 | 157 | 49 |
| 50 | 25·0 | 30·0 | 35·0 | 40·0 | 45·0 | 50·0 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 50 |
| 51 | 25·5 | 30·6 | 35·7 | 40·8 | 45·9 | 51·0 | 61 | 71 | 82 | 92 | 102 | 112 | 122 | 133 | 143 | 153 | 163 | 51 |
| 52 | 26·0 | 31·2 | 36·4 | 41·6 | 46·8 | 52·0 | 62 | 73 | 83 | 94 | 104 | 114 | 124 | 135 | 146 | 156 | 166 | 52 |
| 53 | 26·5 | 31·8 | 37·1 | 42·4 | 47·7 | 53·0 | 64 | 74 | 85 | 95 | 106 | 117 | 127 | 138 | 148 | 159 | 170 | 53 |
| 54 | 27·0 | 32·4 | 37·8 | 43·2 | 48·6 | 54·0 | 65 | 76 | 86 | 97 | 108 | 119 | 130 | 140 | 151 | 162 | 173 | 54 |
| 55 | 27·5 | 33·0 | 38·5 | 44·0 | 49·5 | 55·0 | 66 | 77 | 88 | 99 | 110 | 121 | 132 | 143 | 154 | 165 | 176 | 55 |
| 56 | 28·0 | 33·6 | 39·2 | 44·8 | 50·4 | 56·0 | 67 | 78 | 90 | 101 | 112 | 123 | 134 | 146 | 157 | 168 | 179 | 56 |
| 57 | 28·5 | 34·2 | 39·9 | 45·6 | 51·3 | 57·0 | 68 | 80 | 91 | 103 | 114 | 125 | 137 | 148 | 160 | 171 | 182 | 57 |
| 58 | 29·0 | 34·8 | 40·6 | 46·4 | 52·2 | 58·0 | 70 | 81 | 93 | 104 | 116 | 128 | 139 | 151 | 162 | 174 | 186 | 58 |
| 59 | 29·5 | 35·4 | 41·3 | 47·2 | 53·1 | 59·0 | 71 | 83 | 94 | 106 | 118 | 130 | 142 | 153 | 165 | 177 | 189 | 59 |
| 60 | 30·0 | 36·0 | 42·0 | 48·0 | 54·0 | 60·0 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 60 |
| | 50 | 60 | 70 | 80 | 90 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | |

## FOR INTERPOLATION.

| Unit or " | Difference for 100. | | | | | | | | | | | | | | | | | Unit or " |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 340 | 360 | 380 | 400 | 420 | 440 | 460 | 480 | 500 | 520 | 540 | 560 | 580 | 600 | 620 | 640 | 660 | |
| 1 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 7 | 1 |
| 2 | 7 | 7 | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 12 | 13 | 13 | 2 |
| 3 | 10 | 11 | 11 | 12 | 13 | 13 | 14 | 14 | 15 | 16 | 16 | 17 | 17 | 18 | 19 | 19 | 20 | 3 |
| 4 | 14 | 14 | 15 | 16 | 17 | 18 | 19 | 19 | 20 | 21 | 22 | 22 | 23 | 24 | 25 | 26 | 26 | 4 |
| 5 | 17 | 18 | 19 | 20 | 21 | 22 | 24 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 5 |
| 6 | 20 | 22 | 23 | 24 | 25 | 26 | 29 | 29 | 30 | 31 | 32 | 34 | 35 | 36 | 37 | 38 | 40 | 6 |
| 7 | 24 | 25 | 27 | 28 | 29 | 31 | 33 | 34 | 35 | 36 | 38 | 39 | 41 | 42 | 43 | 45 | 46 | 7 |
| 8 | 27 | 29 | 30 | 32 | 34 | 35 | 38 | 38 | 40 | 42 | 43 | 45 | 46 | 48 | 50 | 51 | 53 | 8 |
| 9 | 31 | 32 | 34 | 36 | 38 | 40 | 42 | 43 | 45 | 47 | 49 | 50 | 52 | 54 | 56 | 58 | 59 | 9 |
| 10 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 10 |
| 11 | 37 | 40 | 42 | 44 | 46 | 48 | 51 | 53 | 55 | 57 | 59 | 62 | 64 | 66 | 68 | 70 | 73 | 11 |
| 12 | 41 | 43 | 46 | 48 | 50 | 53 | 55 | 58 | 60 | 62 | 65 | 67 | 70 | 72 | 74 | 77 | 79 | 12 |
| 13 | 44 | 47 | 49 | 52 | 55 | 57 | 60 | 62 | 65 | 68 | 70 | 73 | 75 | 78 | 81 | 83 | 86 | 13 |
| 14 | 48 | 50 | 53 | 56 | 59 | 62 | 64 | 67 | 70 | 73 | 76 | 78 | 81 | 84 | 87 | 90 | 92 | 14 |
| 15 | 51 | 54 | 57 | 60 | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 90 | 93 | 96 | 99 | 15 |
| 16 | 54 | 58 | 61 | 64 | 67 | 70 | 74 | 77 | 80 | 83 | 86 | 90 | 93 | 96 | 99 | 102 | 106 | 16 |
| 17 | 58 | 61 | 65 | 68 | 71 | 75 | 78 | 82 | 85 | 88 | 92 | 95 | 99 | 102 | 105 | 109 | 112 | 17 |
| 18 | 61 | 65 | 68 | 72 | 76 | 79 | 83 | 84 | 90 | 94 | 97 | 101 | 104 | 108 | 112 | 115 | 119 | 18 |
| 19 | 65 | 68 | 72 | 76 | 80 | 84 | 87 | 91 | 95 | 99 | 103 | 106 | 110 | 114 | 118 | 122 | 125 | 19 |
| 20 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 | 104 | 108 | 112 | 116 | 120 | 124 | 128 | 132 | 20 |
| 21 | 71 | 76 | 80 | 84 | 88 | 92 | 97 | 101 | 105 | 109 | 113 | 118 | 122 | 126 | 130 | 134 | 139 | 21 |
| 22 | 75 | 79 | 84 | 88 | 92 | 97 | 101 | 106 | 110 | 114 | 119 | 123 | 128 | 132 | 136 | 141 | 145 | 22 |
| 23 | 78 | 83 | 87 | 92 | 97 | 101 | 106 | 110 | 115 | 120 | 124 | 129 | 133 | 138 | 143 | 147 | 152 | 23 |
| 24 | 82 | 86 | 91 | 96 | 101 | 106 | 110 | 115 | 120 | 125 | 130 | 134 | 139 | 144 | 149 | 154 | 158 | 24 |
| 25 | 85 | 90 | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 145 | 150 | 155 | 160 | 165 | 25 |
| 26 | 88 | 94 | 99 | 104 | 109 | 114 | 120 | 125 | 130 | 135 | 140 | 146 | 151 | 156 | 161 | 166 | 172 | 26 |
| 27 | 92 | 97 | 103 | 108 | 113 | 119 | 124 | 130 | 135 | 140 | 146 | 151 | 157 | 162 | 167 | 173 | 178 | 27 |
| 28 | 95 | 101 | 106 | 112 | 118 | 123 | 129 | 134 | 140 | 146 | 151 | 157 | 162 | 168 | 174 | 179 | 185 | 28 |
| 29 | 99 | 104 | 110 | 116 | 122 | 128 | 133 | 139 | 145 | 151 | 157 | 162 | 168 | 174 | 180 | 186 | 191 | 29 |
| 30 | 102 | 108 | 114 | 120 | 126 | 132 | 138 | 144 | 150 | 156 | 162 | 168 | 174 | 180 | 186 | 192 | 198 | 30 |
| 31 | 105 | 112 | 118 | 124 | 130 | 136 | 143 | 149 | 155 | 161 | 167 | 174 | 180 | 186 | 192 | 198 | 205 | 31 |
| 32 | 109 | 115 | 122 | 128 | 134 | 141 | 147 | 154 | 160 | 166 | 173 | 179 | 186 | 192 | 198 | 205 | 211 | 32 |
| 33 | 112 | 119 | 125 | 132 | 139 | 145 | 152 | 158 | 165 | 172 | 178 | 185 | 191 | 198 | 205 | 211 | 218 | 33 |
| 34 | 116 | 122 | 129 | 136 | 143 | 150 | 156 | 163 | 170 | 177 | 184 | 190 | 197 | 204 | 211 | 218 | 224 | 34 |
| 35 | 119 | 126 | 133 | 140 | 147 | 154 | 161 | 168 | 175 | 182 | 189 | 196 | 203 | 210 | 217 | 224 | 231 | 35 |
| 36 | 122 | 130 | 137 | 144 | 151 | 158 | 166 | 173 | 180 | 187 | 194 | 202 | 209 | 216 | 223 | 230 | 238 | 36 |
| 37 | 126 | 133 | 141 | 148 | 155 | 163 | 170 | 178 | 185 | 192 | 200 | 207 | 215 | 222 | 229 | 237 | 244 | 37 |
| 38 | 129 | 137 | 144 | 152 | 160 | 167 | 175 | 182 | 190 | 198 | 205 | 213 | 220 | 228 | 236 | 243 | 251 | 38 |
| 39 | 133 | 140 | 148 | 156 | 164 | 172 | 180 | 187 | 195 | 203 | 211 | 218 | 226 | 234 | 242 | 250 | 257 | 39 |
| 40 | 136 | 144 | 152 | 160 | 168 | 176 | 184 | 192 | 200 | 208 | 216 | 224 | 232 | 240 | 248 | 256 | 264 | 40 |
| 41 | 139 | 148 | 156 | 164 | 172 | 180 | 189 | 197 | 205 | 213 | 221 | 230 | 238 | 246 | 254 | 262 | 271 | 41 |
| 42 | 143 | 151 | 160 | 168 | 176 | 185 | 193 | 202 | 210 | 218 | 227 | 235 | 244 | 252 | 260 | 269 | 277 | 42 |
| 43 | 146 | 155 | 163 | 172 | 181 | 189 | 198 | 206 | 215 | 224 | 232 | 241 | 249 | 258 | 267 | 275 | 284 | 43 |
| 44 | 150 | 158 | 167 | 176 | 185 | 194 | 202 | 211 | 220 | 229 | 238 | 246 | 255 | 264 | 273 | 282 | 290 | 44 |
| 45 | 153 | 162 | 171 | 180 | 189 | 198 | 207 | 216 | 225 | 234 | 243 | 252 | 261 | 270 | 279 | 288 | 297 | 45 |
| 46 | 156 | 166 | 175 | 184 | 193 | 203 | 212 | 221 | 230 | 239 | 248 | 258 | 267 | 276 | 285 | 294 | 304 | 46 |
| 47 | 160 | 169 | 179 | 188 | 197 | 208 | 216 | 226 | 235 | 244 | 254 | 263 | 273 | 282 | 291 | 301 | 310 | 47 |
| 48 | 163 | 173 | 182 | 192 | 202 | 212 | 221 | 230 | 240 | 250 | 259 | 269 | 278 | 288 | 298 | 307 | 317 | 48 |
| 49 | 167 | 176 | 186 | 196 | 206 | 217 | 225 | 235 | 245 | 255 | 265 | 274 | 284 | 294 | 304 | 314 | 323 | 49 |
| 50 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 310 | 320 | 330 | 50 |
| 51 | 173 | 184 | 194 | 204 | 214 | 224 | 235 | 245 | 255 | 265 | 275 | 286 | 296 | 306 | 316 | 326 | 337 | 51 |
| 52 | 177 | 187 | 198 | 208 | 218 | 229 | 239 | 250 | 260 | 270 | 281 | 291 | 302 | 312 | 322 | 333 | 343 | 52 |
| 53 | 180 | 191 | 201 | 212 | 223 | 233 | 244 | 254 | 265 | 276 | 286 | 297 | 307 | 318 | 329 | 339 | 350 | 53 |
| 54 | 184 | 194 | 205 | 216 | 227 | 238 | 248 | 260 | 270 | 281 | 292 | 302 | 313 | 324 | 335 | 346 | 356 | 54 |
| 55 | 187 | 198 | 209 | 220 | 231 | 242 | 253 | 264 | 275 | 286 | 297 | 308 | 319 | 330 | 341 | 352 | 363 | 55 |
| 56 | 190 | 202 | 213 | 224 | 235 | 246 | 258 | 269 | 280 | 291 | 302 | 314 | 325 | 336 | 347 | 358 | 370 | 56 |
| 57 | 194 | 205 | 217 | 228 | 239 | 251 | 262 | 274 | 285 | 296 | 308 | 319 | 331 | 342 | 353 | 365 | 376 | 57 |
| 58 | 197 | 209 | 220 | 232 | 244 | 255 | 267 | 278 | 290 | 302 | 313 | 325 | 336 | 348 | 360 | 371 | 383 | 58 |
| 59 | 201 | 212 | 224 | 236 | 248 | 260 | 271 | 283 | 295 | 307 | 319 | 330 | 342 | 354 | 366 | 378 | 389 | 59 |
| 60 | 204 | 216 | 228 | 240 | 252 | 264 | 276 | 288 | 300 | 312 | 324 | 336 | 348 | 360 | 372 | 384 | 396 | 60 |
| | 340 | 360 | 380 | 400 | 420 | 440 | 460 | 480 | 500 | 520 | 540 | 560 | 580 | 600 | 620 | 640 | 660 | |

78-363



## FOR INTERPOLATION.

| Unit or // | Difference for 100. | | | | | | | | | | | | | | | | | Unit or // |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 680 | 700 | 720 | 740 | 760 | 780 | 800 | 820 | 840 | 860 | 880 | 900 | 920 | 940 | 960 | 980 | 1000 | |
| 1 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 | 10 | 10 | 10 | 1 |
| 2 | 14 | 14 | 14 | 15 | 15 | 16 | 16 | 16 | 17 | 17 | 18 | 18 | 19 | 19 | 19 | 20 | 20 | 2 |
| 3 | 20 | 21 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 26 | 26 | 27 | 29 | 28 | 29 | 29 | 30 | 3 |
| 4 | 27 | 28 | 29 | 30 | 30 | 31 | 32 | 33 | 34 | 34 | 35 | 36 | 38 | 38 | 38 | 39 | 40 | 4 |
| 5 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 5 |
| 6 | 41 | 42 | 43 | 44 | 46 | 47 | 48 | 49 | 50 | 52 | 53 | 54 | 55 | 56 | 58 | 59 | 60 | 6 |
| 7 | 48 | 49 | 50 | 52 | 53 | 55 | 56 | 57 | 59 | 60 | 62 | 63 | 64 | 66 | 67 | 69 | 70 | 7 |
| 8 | 54 | 56 | 58 | 59 | 61 | 62 | 64 | 66 | 67 | 69 | 70 | 72 | 74 | 75 | 77 | 78 | 80 | 8 |
| 9 | 61 | 63 | 65 | 67 | 68 | 70 | 72 | 74 | 76 | 77 | 79 | 81 | 83 | 85 | 86 | 88 | 90 | 9 |
| 10 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 10 |
| 11 | 75 | 77 | 79 | 81 | 84 | 86 | 88 | 90 | 92 | 95 | 97 | 99 | 101 | 103 | 106 | 108 | 110 | 11 |
| 12 | 82 | 84 | 86 | 89 | 91 | 94 | 96 | 98 | 101 | 103 | 106 | 108 | 110 | 113 | 115 | 118 | 120 | 12 |
| 13 | 88 | 91 | 94 | 96 | 99 | 101 | 104 | 107 | 109 | 112 | 114 | 117 | 120 | 122 | 125 | 127 | 130 | 13 |
| 14 | 95 | 98 | 101 | 104 | 106 | 109 | 112 | 115 | 118 | 120 | 123 | 126 | 129 | 132 | 134 | 137 | 140 | 14 |
| 15 | 102 | 105 | 108 | 111 | 114 | 117 | 120 | 123 | 126 | 129 | 132 | 135 | 138 | 141 | 144 | 147 | 150 | 15 |
| 16 | 109 | 112 | 115 | 118 | 122 | 125 | 128 | 131 | 134 | 138 | 141 | 144 | 147 | 150 | 154 | 157 | 160 | 16 |
| 17 | 116 | 119 | 122 | 126 | 129 | 133 | 136 | 139 | 143 | 146 | 150 | 153 | 156 | 160 | 163 | 167 | 170 | 17 |
| 18 | 122 | 126 | 130 | 133 | 137 | 140 | 144 | 148 | 151 | 155 | 158 | 162 | 166 | 169 | 173 | 176 | 180 | 18 |
| 19 | 129 | 133 | 137 | 141 | 144 | 148 | 152 | 156 | 160 | 163 | 167 | 171 | 175 | 179 | 182 | 186 | 190 | 19 |
| 20 | 136 | 140 | 144 | 148 | 152 | 156 | 160 | 164 | 168 | 172 | 176 | 180 | 184 | 188 | 192 | 196 | 200 | 20 |
| 21 | 143 | 147 | 151 | 155 | 160 | 164 | 168 | 172 | 176 | 181 | 185 | 189 | 193 | 197 | 202 | 206 | 210 | 21 |
| 22 | 150 | 154 | 158 | 163 | 167 | 172 | 176 | 180 | 185 | 189 | 194 | 198 | 202 | 207 | 211 | 216 | 220 | 22 |
| 23 | 156 | 161 | 166 | 170 | 175 | 179 | 184 | 189 | 193 | 198 | 203 | 207 | 212 | 216 | 221 | 225 | 230 | 23 |
| 24 | 163 | 168 | 173 | 178 | 182 | 187 | 192 | 197 | 202 | 206 | 212 | 216 | 221 | 226 | 230 | 235 | 240 | 24 |
| 25 | 170 | 175 | 180 | 185 | 190 | 195 | 200 | 205 | 210 | 215 | 220 | 225 | 230 | 235 | 240 | 245 | 250 | 25 |
| 26 | 177 | 182 | 187 | 192 | 198 | 203 | 208 | 213 | 218 | 224 | 229 | 234 | 239 | 244 | 250 | 255 | 260 | 26 |
| 27 | 184 | 189 | 194 | 200 | 205 | 211 | 216 | 221 | 227 | 232 | 238 | 243 | 248 | 253 | 259 | 265 | 270 | 27 |
| 28 | 190 | 196 | 202 | 207 | 213 | 218 | 224 | 230 | 235 | 241 | 246 | 252 | 258 | 263 | 269 | 274 | 280 | 28 |
| 29 | 197 | 203 | 209 | 215 | 220 | 226 | 232 | 238 | 244 | 249 | 255 | 261 | 267 | 273 | 278 | 284 | 290 | 29 |
| 30 | 204 | 210 | 216 | 222 | 228 | 234 | 240 | 246 | 252 | 258 | 264 | 270 | 276 | 282 | 288 | 294 | 300 | 30 |
| 31 | 211 | 217 | 223 | 229 | 236 | 242 | 248 | 254 | 260 | 267 | 273 | 279 | 285 | 291 | 298 | 304 | 310 | 31 |
| 32 | 218 | 224 | 230 | 237 | 243 | 250 | 256 | 262 | 269 | 275 | 282 | 288 | 294 | 301 | 307 | 314 | 320 | 32 |
| 33 | 224 | 231 | 238 | 244 | 251 | 257 | 264 | 271 | 277 | 284 | 290 | 297 | 304 | 310 | 317 | 323 | 330 | 33 |
| 34 | 231 | 238 | 245 | 252 | 258 | 265 | 272 | 279 | 286 | 292 | 299 | 306 | 310 | 320 | 326 | 333 | 340 | 34 |
| 35 | 238 | 245 | 252 | 259 | 266 | 273 | 280 | 287 | 294 | 301 | 308 | 315 | 322 | 329 | 336 | 343 | 350 | 35 |
| 36 | 245 | 252 | 259 | 266 | 274 | 281 | 288 | 295 | 302 | 310 | 317 | 324 | 331 | 338 | 346 | 353 | 360 | 36 |
| 37 | 252 | 259 | 266 | 274 | 281 | 289 | 296 | 303 | 311 | 318 | 326 | 333 | 340 | 348 | 355 | 363 | 370 | 37 |
| 38 | 258 | 266 | 274 | 281 | 289 | 296 | 304 | 312 | 319 | 327 | 334 | 342 | 350 | 357 | 365 | 372 | 380 | 38 |
| 39 | 265 | 273 | 281 | 289 | 296 | 304 | 312 | 320 | 328 | 335 | 343 | 351 | 359 | 367 | 374 | 382 | 390 | 39 |
| 40 | 272 | 280 | 288 | 296 | 304 | 312 | 320 | 328 | 336 | 344 | 352 | 360 | 368 | 376 | 384 | 392 | 400 | 40 |
| 41 | 279 | 287 | 295 | 303 | 312 | 320 | 328 | 336 | 344 | 353 | 361 | 369 | 377 | 385 | 394 | 402 | 410 | 41 |
| 42 | 286 | 294 | 302 | 311 | 319 | 328 | 336 | 344 | 353 | 361 | 370 | 378 | 386 | 395 | 403 | 412 | 420 | 42 |
| 43 | 292 | 301 | 310 | 318 | 327 | 335 | 344 | 353 | 361 | 370 | 378 | 387 | 396 | 404 | 413 | 421 | 430 | 43 |
| 44 | 299 | 308 | 317 | 326 | 334 | 343 | 352 | 361 | 370 | 378 | 387 | 396 | 405 | 414 | 422 | 431 | 440 | 44 |
| 45 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 387 | 396 | 405 | 414 | 423 | 432 | 441 | 450 | 45 |
| 46 | 313 | 322 | 331 | 340 | 350 | 359 | 368 | 377 | 386 | 396 | 405 | 414 | 423 | 432 | 442 | 451 | 460 | 46 |
| 47 | 320 | 329 | 338 | 348 | 357 | 367 | 376 | 385 | 395 | 404 | 414 | 423 | 432 | 442 | 451 | 461 | 470 | 47 |
| 48 | 326 | 336 | 346 | 355 | 365 | 374 | 384 | 394 | 403 | 413 | 422 | 432 | 442 | 451 | 461 | 470 | 480 | 48 |
| 49 | 333 | 343 | 353 | 363 | 372 | 382 | 392 | 402 | 412 | 421 | 431 | 441 | 451 | 461 | 470 | 480 | 490 | 49 |
| 50 | 340 | 350 | 360 | 370 | 380 | 390 | 400 | 410 | 420 | 430 | 440 | 450 | 460 | 470 | 480 | 490 | 500 | 50 |
| 51 | 347 | 357 | 367 | 377 | 388 | 398 | 408 | 418 | 428 | 439 | 449 | 459 | 469 | 479 | 490 | 500 | 510 | 51 |
| 52 | 354 | 364 | 374 | 385 | 395 | 406 | 416 | 426 | 437 | 447 | 458 | 468 | 478 | 489 | 499 | 510 | 520 | 52 |
| 53 | 360 | 371 | 382 | 392 | 403 | 413 | 424 | 435 | 445 | 456 | 466 | 477 | 488 | 498 | 509 | 519 | 530 | 53 |
| 54 | 367 | 378 | 389 | 400 | 410 | 421 | 432 | 443 | 454 | 464 | 475 | 486 | 497 | 508 | 518 | 529 | 540 | 54 |
| 55 | 374 | 385 | 396 | 407 | 418 | 429 | 440 | 451 | 462 | 473 | 484 | 495 | 506 | 517 | 528 | 539 | 550 | 55 |
| 56 | 381 | 392 | 403 | 414 | 426 | 437 | 448 | 459 | 470 | 482 | 493 | 504 | 515 | 526 | 538 | 549 | 560 | 56 |
| 57 | 388 | 399 | 410 | 422 | 433 | 447 | 456 | 467 | 479 | 490 | 502 | 513 | 524 | 536 | 547 | 559 | 570 | 57 |
| 58 | 394 | 406 | 418 | 429 | 441 | 452 | 464 | 476 | 487 | 499 | 510 | 522 | 534 | 545 | 557 | 568 | 580 | 58 |
| 59 | 401 | 413 | 425 | 437 | 448 | 460 | 472 | 484 | 496 | 507 | 519 | 531 | 543 | 555 | 566 | 578 | 590 | 59 |
| 60 | 408 | 420 | 432 | 444 | 456 | 468 | 480 | 492 | 504 | 516 | 528 | 540 | 552 | 564 | 576 | 588 | 600 | 60 |
| | 680 | 700 | 720 | 740 | 760 | 780 | 800 | 820 | 840 | 860 | 880 | 900 | 920 | 940 | 960 | 980 | 1000 | |

7/32

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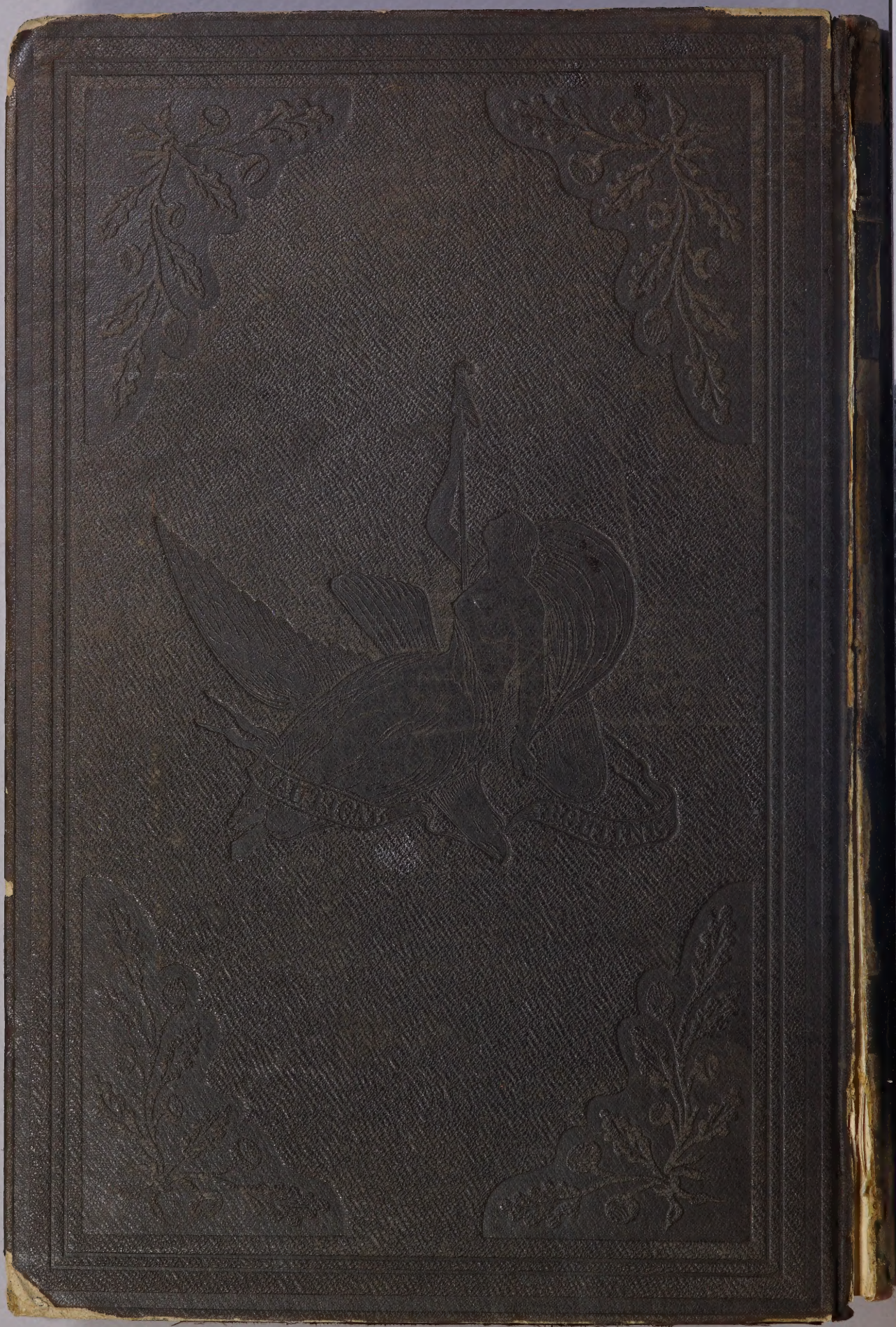
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